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Problems and Organization Needs of the Division of Administrative Officers

By S. C. HOLLISTER

Chairman; Dean, College of Engineering, Cornell University

With the successful conclusion of the war and the beginning of the peace, we pass from one era into a new one in higher education. The war years have brought many new factors to the fore in our social system, in our economic outlook, and in our scientific and technological progress. These must be integrated into our educational philosophy and procedures. The extent to which the various units of our educational system can work together and coordinate their several functions will measure the promptness and effectiveness with which the challenging problems presented may be resolved, and the resulting solutions implemented.

The public is conscious of a new social significance of science and technology. It is now vividly apparent that this awareness of the contributions of science and technology to our way of life comprehends not only the immediate providing of conveniences for living but also the far-reaching effect upon our economy and our international social and political relations. It is the task of higher education to maintain a true perspective of the pertinent influences, and engineering schools must share in this responsibility.

It is inevitable, with increasing recognition of the function of science and engineering, that agencies of government will give increasing attention to matters in these fields. Evidence of this is to be found in a number of bills before the Congress and the State Legislatures. Engineering college administration must be in a position to express itself as a unit of the educational field on such matters as they arise.

At the present moment much attention is being given by your officers to the policy of selective service which fails to provide for the prompt resumption of the training of scientists and engineers and which fails to recognize the national interest in such training. During the war we were the only country among the larger allied powers in which scientific and technical training was not continued at a substantially normal rate. Even if selective service now provided for a normal flow to the engineering colleges this country would be short an estimated 55,000 engineering graduates by 1949, the earliest date a senior class of pre-war size can be graduated. This denies to industry and government the equivalent output of the engineering colleges of four normal years. To pursue this policy longer will jeopardize our present high position in science and engineering among the nations.

The provision for subsidies for education and research in scientific and

technological fields; the diversion of an adequate supply of surplus war property to augment equipment of educational institutions; the consideration by competent educators of the proposed plan for universal military training—these and others are being actively followed by the Administrative Division of the Society because of their obvious interest and importance to engineering education.

Since the Cincinnati Convention the Society, under its President, has taken vigorous action in matters as they have developed. It is clear that it is of vital importance to the engineering educational field that the Society continue this activity.

The structure of the Society does not now provide constitutionally for the activities that the Administrative Division will have to undertake in the interest of the Society. It is the writer's conviction that the proposed revision of the Constitution will furnish much needed strength to the Administrative Division's function on behalf of the Society, judged by first-hand acquaintance with activities relating to the problems of the present and future.

English and the Humanistic-Social Division

By KARL O. THOMPSON

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The recognition by the Society for the Promotion of Engineering Education of a Humanistic-Social Division of studies alongside a Scientific-Technological Division was a distinct advancement. Such action has long been desired by teachers of English in engineering colleges. If the recognition will also be accorded by the rank and file of teachers of engineering subjects, the gain will be clinched.

Such official recognition by Presidents and Deans has brought a change in the problems of the teachers of English. Our problems are now internal rather than external; the solution of the problems, however, concerns all who share in the privilege of supervising the education of engineers. Not all of our problems are new, but we may find it profitable to re-study old and new alike.

The meaning of the term Humanistic-Social and the statement of the function of the courses included, considered as a group, is the first problem. The aims of the two Divisions are set forth by the Committee on Engineering Education After the War. With the statement concerning the Scientific-Technological Division there will be little disagreement, certainly very little by teachers of English. The studies in that Division deal with Nature, the material world and its resources, and the means and processes of adapting these to the use of mankind. They are practical and they are arranged in a logical sequence. The degree of Bachelor of Science (or its equivalent) has been awarded after four years of work and professional fitness has been expected at the time of the granting of the degree. If there has been a major and a minor grouping, both have quite likely been in the same department of engineering. The time allotted to subjects in the Humanistic-Social Division has been from ten to seventeen per cent. Very few graduates have gone into technical journalism or even into teaching.

With the aims and scope of the Humanistic-Social Division as stated by the Committee, teachers of English feel less certain. The order of the aims as given may mean nothing, but the description of the objectives needs clarification in several particulars. Humanistic studies or "the Humanities" have traditionally taken up the character of man, his thoughts, his philosophies, his ideals, and their interpretations. The social studies, if they are differentiated from the humanities, have taken up the history of mankind, the relationships of man as a member of the human race or of groups of his kind, his duties and responsibilities toward his fellows, and the theories of group organization. The former studies stress the values of life, the latter stress the means of measuring and comparing human attainments. The

former look at man as a personality, the latter look at him as an individual in a group. Together, the two groups have dealt with moral, psychological, and social concepts that show that humane living is desirable and that cooperative living is possible. Science has not been omitted, as the story of liberal arts colleges will quickly show, and the place of science has been steadily expanding in liberal curricula. From the days when science was natural philosophy to the latest theory in pure physics, the study of science has contributed to the cultural growth of mankind. It has been felt necessary to a well rounded education. Disregarding the period and the institutions in which an unrestricted elective system prevailed, we know that educational systems generally have required a balance between the humanities and the sciences. The graduate of a liberal arts college, however, would not be fitted immediately for a professional career, but would be in a position to select any one of several career possibilities, or to enter at once the competition of business or industry.

Now engineering colleges are recognizing this two-fold objective. They are broadening their base and are aiming at a more rounded education. Non-engineering subjects are given a higher status than that of mere service courses and will now not only contribute to professional success, but be vital to the total education. This means that a ribbon of non-engineering courses will run through the four years of college, although an essentially professional objective is maintained. The interrelationship of the practical and the cultural is clearly accepted. This broadening of the base of engineering education may do things to some of the specialized courses formerly given in the undergraduate curriculum and give an impetus to a fifth year for all who wish to go into research work, looking toward a Master's degree. This tendency will parallel the type of training long associated with the liberal arts colleges, at the same time preserving the preponderance of technical work. The Committee recommends a proportion of four or three to one between the scientific-technological and humanistic-social groups. This is not far from the proportion, in reverse, in an average course in a liberal arts college.

All this tends to shift the tasks of the teachers of English in engineering colleges. First, let it be said that teachers of English must and can adapt themselves better to the engineering atmosphere and try to understand more adequately the professional standards and needs of the graduates. This will not always be easy and will call for closer cooperation throughout the whole faculty than has often prevailed. The teacher of English need not cease to be a specialist in his field, but he must be a part of the engineering educative process. Next, the task of the teachers of English is turned toward the personal enrichment of the engineering student. It is more interpretive, more stimulating, more educative, not devoted solely to developing skills in writing. It requires the teacher to stress organization of thought, not mere accumulation of knowledge; to emphasize the power of analysis rather than absorption of rules; to put his time on building up standards of judgment rather than on routine drill. The teachers of English and of social sciences have been given a new part in the training of engineers.

Instead of trying to re-write the six aims presented in the Report of the Committee, we may put the aims of

engineering education as a whole in a brief and general form, a form that will appeal to all of us. Without elaboration, three aspects of engineering education are being set forth somewhat as follows: (1) that professional engineers (the graduates of engineering colleges) in being given the technical training in classroom and laboratory deemed essential, shall direct their knowledge and skill to the service of society; (2) that they shall recognize the importance of human relationships in their professional and business duties and shall accept leadership in working with others; and (3) that they shall eagerly cultivate the personal attainments and satisfactions of a well rounded life. Such a statement clearly puts the professional interests of the engineer first, but more clearly than ever before, perhaps, stresses his civic and public obligations and the qualities of a rich and meaningful personal life. A better perspective is secured than before. To those of us who have taught the humanities this is not merely recognition but adoption. Our problem is shifting to that of finding all the ways possible for the enrichment of the contribution that we can make to the professional efficiency of the graduate engineer.

Let us now look at the distribution of time and subject matter within the Humanistic-Social Division. What courses are most essential in the rounding out process? Accepting the suggestions of the S.P.E.E. Committee of a maximum of twenty-five per cent of time being given to the Humanistic-Social group, we will have at least one course every term for the full four years or eight semester courses. In addition to the required courses there will be certain elective or optional courses, amounting to perhaps four semester courses. Twelve semester courses will mean from thirty to forty semester credit hours in the full engineering four-year period. The elective principle can, of course, with some limitations, be applied also to courses in technical fields, with a definite broadening of the education. Provided some clear definitions are drawn in the classification of subjects as technical or non-technical, there will be no objection by anyone to the extension of the elective principle. Such definitions have not always been made. Some technical courses have been considered as non-technical electives for students in other engineering departments. The difficulty here is heightened by a necessary admission that many courses *may* be taught with a cultural emphasis if the teacher wishes to give that emphasis. The technical courses in one department may well be offered to students in another department with a more liberal interpretation than that which is given in the original department. Such a plan would broaden the base of the general, fundamental courses, displacing some of the more specialized courses for some students. But the prerogative of offering non-technical options should for the most part be given to the teachers in the Humanistic-Social Division. Two sets of options that would not interfere is the better plan, one set in the technical field and the other set in the non-technical field. But let us turn again to the required courses that will make the ribbon of non-technical work through the whole four-year period.

From within the Humanistic-Social Division let us put down ten courses that will provide the required studies. As a tentative list, take this: Argumentation and Debate, Expository Writing with a chiefly technical ap-

plication, Expository Writing with a literary application (the Essay), Types of Literature (as distinct from a Survey course), Great Drama, Public Speaking, Elementary Economics, History of Europe (the World) Since Napoleon, History of Science or Technological Development, and General Psychology. Three or four electives may be chosen from the following list: American Literature, American History, Contemporary Literature, Economic Geography, Philosophy, Labor Problems (or Management), Sociology, Music Appreciation (or the study of some other of the Fine Arts), and Journalism. This offers approximately a fifty-fifty choice between the two departments of Language and Literature and Social Studies. In regard to a course in Composition, such a course as is usually called Freshman English, two remarks must be made. Much can be said in favor of such a course in view of the variations in thoroughness in high schools and of the fundamental nature of the work. But first, it is work that in theory belongs to the high schools or even the grade schools. Elementary English composition, like arithmetic, ought to be presupposed in a college student's equipment. Advanced courses in Creative Writing or in specialized fields such as Journalism are of college grade, but if college education means anything it ought to be able to demand certain abilities in its applicants for admission. Among such qualifications would surely be the ability to perform the elementary processes of numbering and the ability to write acceptable English prose. As a concession to the experience of all of us, that we tend to become careless or forgetful, colleges may well provide quick reviews or practice periods as extra, non-credit classes. The other point is that Composition is distinctly a tool course, and if it is deemed necessary to include it, time for it should not come out of the time allotted to the Humanistic-Social Division. Most of the work in English in college should, therefore, be in Literature or in certain advanced courses in writing in which qualities of style are stressed.

Some other courses that have some cultural importance are also classified here in the Scientific-Technological Division. Examples would be: Business Law, Engineering Administration, and Accountancy. Some other subjects might well be included, but would not be whole semester courses; such would be: the Engineering Profession, Professional Ethics, History of Latin America, Political Organizations or Systems (an expanded Civics), and the Theory of Evolution. Such topics may be made parts of other standard courses. The courses in literature as taught in engineering colleges will undoubtedly have some characteristics of their own. The material will be inclusive rather than specialized; the breadth, however, will be that of form rather than that of time. Types courses are better than Survey courses, because Types courses include examples from several national or racial backgrounds, in a comparative sort of way. Specimens of literature should be read for their ideas and their style, rather than for their detailed biographical or historical information. They should present human problems and human philosophies, rather than offer research opportunities in literary scholarship. They should illumine the times out of which they come, rather than be peculiar or queer pieces of writing. The glory of literature is the skill of the author in putting into words interesting or significant experiences. It is

the old combination of truth and beauty. Literature has a stimulating effect upon the imagination of its readers and assists them to develop standards of good judgment in the realms of the artistic. By the sheer beauty of execution or by worth of thought an author may be important, but chiefly by a combination of these two achievements does he attain significance. College should bring to its students a rich experience in those courses in which human life and human personalities are described.

To some extent these results may be reached in courses in history, economics, geography, sociology, or political science, but for the most part books in these subjects approach the usual textbook point of view in which factual information or its interpretation is foremost. The purpose in the studies in the social field is to learn about man—his development, the organizations he has set up, the material foundations of his life, the communal relationships he has revealed—and these differ from the purposes of the study of literature. They are taught with a semi-professional bearing; they are concerned with factual, statistical, and legalistic considerations. Some valuable skills or techniques are derived from them and their predictive or guiding value is noteworthy, but there is lacking the full measure of individual stimulation or personal appeal that is attained through literature. Certainly the teaching of these subjects is the province of men trained in ways quite different from those that the teachers of English have followed.

Another problem arises here. Can literature be combined with the material of the social studies? Can English teachers use the textbooks of the social science courses? Some have felt that that is possible, even extending the idea to include some of the technical subjects. Teachers of English can give grades on the written work prepared for other courses, but most of us feel that we cannot teach English composition and certainly not literature in that way. We can be helpful as advisers and editors provided that the responsibility for the subject matter is shared by others well qualified in the field involved. The word *integration* is used by some to apply to such cooperation, but classroom procedures require rather different teaching skills. Much the same objection applies to omnibus courses that crowd a little bit of everything into a poorly-organized term's work. Catch-all courses lack appeal to disciplined minds. The scientific method and the cultural viewpoint can both be developed and displayed in the same person, but hardly by using one textbook or by making a new alloy of subject matter.

Another problem arises in regard to Modern Languages. Should the Humanistic-Social Division include them with time and space provided? Recently the emphasis on German or Spanish, the two languages most frequently included, has decreased. Even if a place for one or more of the languages is found, the value to the engineer is admittedly practical, either for gaining information of technical processes or for communication in business and industry. Languages belong to the tool classification and are to be assigned to the Scientific-Technological Division. Language in this sense includes the correct use of English, as already noted. Language is a fundamental tool of all education, and a study of language as distinct from literature is not one of major cultural value.

The teaching problem is found in English as in every field. A teacher should have had some guidance in the methods and skills of classroom conduct. Inasmuch as engineering schools do not aim to prepare men for the teaching profession, some outside provision will have to be made for the acquisition of the desired techniques by teachers of language and literature. The availability of men who will teach in engineering colleges, with its problems different from those of a liberal arts college, is an increasing difficulty. Interchange between the two types of school is not always easy. Teaching ability is as important as research in teachers in an engineering college. Put in extreme language, uninteresting and less profitable subject matter may be made significant by a skilled teacher; and rich and rewarding subject matter may be ruined by an indifferent and bungling teacher. The more strictly technical courses may be given a genuine cultural power by a wise, broadly sympathetic teacher. The chances are somewhat against this being the case, but if all who teach in engineering colleges can have had some training in psychology and the art of teaching as well as a thorough training in their scientific specialty, the whole tone of engineering education will be lifted. Much the same thing may be said about the success of the industrialist or the executive engineer, for both of these as well as the engineer that teaches must deal with persons almost as much as they deal with materials. This modern demand is of course recognized now and is another argument for the Humanistic-Social program. Another remark, often made before, may be re-stated here, that inasmuch as the English language is the medium through which mechanics, metallurgy, physics, chemistry, etc., are taught to students, the insistence by the teachers of these subjects on correctness of vocabulary, grammar, and form (spelling?) will do a great deal to make engineers aware of the constant importance of good writing.

The establishment of the Humanistic-Social Division raises the question of organization and control within the Division at any college. This problem involves several factors, such as the type of institution, the number of courses taught, the size of staff, the budgetary allowance, the facilities of rooms and offices, etc. From what has been said, the conclusion may be drawn that even when the facilities and the number of men available are adequate, there is still a divergence of interests that make a combination of all the work under one administrative head unwise. The requirements of physical space, time in the schedule, and assignment of duties present many difficulties. More important, the policy making and associations with the heads of the engineering departments may easily bring incongruities if not conflicts. The possible, even probable, personal prejudices of a department head will tend to cause friction. The inherent differences between the natures of language and literature and the social studies make it difficult for one man to be entirely fair to all the associated groups or individuals. This is especially true if the head of a combined department has grown up in one of the smaller sections through a long period of years. He will be attempting to occupy not an academic chair but a whole setee. Possibly, however, a single administrative head of an inclusive department may be acceptable, provided that the department sets up standard subdivisions, each with an executive head.

In other words, if the policy determining in English courses and decisions as to methods of teaching as well as of course content are left to those who are trained in that field, and similarily for a sub-department of Social Studies, then a combination of influence in the counsels of the institution as a whole may be strengthened. That objective would be the only one that would warrant an otherwise awkward arrangement. Better even than such a close organization would be that of a Committee, Board, or Staff Faculty. Cooperation, even federation, may be very helpful; amalgamation, combination, or fusion would almost certainly not be advantageous.

If the principle of allotting from one-fifth to one-fourth of the total time for class schedules to the Humanistic-Social Division be followed, then it would be logical to assume that in Steering Committees, Executive Bodies, or Boards of Directors of individual schools, that same proportion of personnel be recognized. The same principle could be further extended to the Boards of Directors or Executive Committees of district and national organizations of engineering societies.

The problems of the English teachers are shifting, but problems are still with us. We in that group have worked with college administrations and with practicing engineers for many years in considerable harmony. We welcome the larger opportunities that are now open to us in the engineering colleges of the country.

The United States Armed Forces Institute Examinations in Mathematics as a Means of Determining Credit in Engineering Mathematics

By JAMES H. ZANT

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As the time draws near for the expected great post-war influx of students into the colleges the importance of some method of determining what college credit a returned man should have for his educational development while in military service becomes more apparent. This is especially true in engineering mathematics. The necessity of sound mathematical knowledge to the engineer and the engineering student has been recognized much more universally since the war started than before. Hence we must search carefully for means of evaluating mathematical knowledge gained through Army and Navy experience in a way that will be fair to the veteran, but we must also be careful not to handicap him by allowing him to take advanced courses in mathematics or engineering for which he is not prepared.

One such means which has been proposed is the United States Armed Forces Institute Examinations. These examinations, often spoken of as the U.S.A.F.I. tests, come highly recommended by the armed forces and will probably be widely used by them and by the Veterans Administration. It is the purpose of this paper to discuss the origin and purposes of the tests, tell where they may be obtained and say something about norms and possible uses. A later paper will discuss the results of the actual use of the tests in some of our colleges.

The U.S.A.F.I. was established to provide off-duty educational opportunities for service personnel and as a part of this program established an Examination Staff at the University of Chicago which constructed the U.S.A.F.I. examinations. These examinations are for the purpose of *"reporting* the educational achievements and status of service personnel to the educational institutions at which these men and women may wish to establish credit."[1] Notice that "achievements and status" are to be *reported.* No institution is required to grant credit on the basis of this evidence. However, it seems apparent that students will come to us with ratings on these tests and we must make some decision regarding them.

In engineering mathematics we shall be concerned with five tests, College Algebra, Plane Trigonometry, Analytic Geometry, Differential Calculus and Integral Calculus. The first forms

[1] The United States Armed Forces, *Manual for Subject Tests,* The American Council on Education, 1944, p. 1.

of these tests were found to be unsatisfactory and are no longer in use.

"In June, 1944, Professor M. H. Stone, Chairman of the War Policy Committee of the American Mathematical Society and the Mathematical Association of America, appointed a Subcommittee on Examinations to advise the Examinations Staff of the United States Armed Forces Institute in connection with examinations in mathematics at the college level to be sponsored by the U.S.A.F.I. This Subcommittee was instituted at the request of Professor R. W. Tyler, Director of the Examinations Staff for the U.S.A.F.I., following initial contact between Professor Tyler and the War Training Programs Subcommittee of the War Policy Committee. The following individuals were appointed to this Subcommittee: Professors Ralph Beatley (Harvard); L. L. Dines (Carnegie Institute of Technology); W. L. Hart (Minnesota); C. C. MacDuffee (Wisconsin); W. T. Reid (Northwestern; Chicago, at time of appointment), Chairman.

"At a meeting of the Subcommittee held early in July 1944, it was decided to concentrate on perfecting the U.S.A.F.I. subject examinations for College Algebra, Plane Trigonometry, Analytic Geometry, and Calculus. The Subcommittee devoted its efforts to this task from that time until November 30, 1944, when the examinations construction project of the U.S.A.F.I. was terminated by the War Department.

"The purpose of these subject examinations is to provide an instrument for evaluating the work of men in courses taken under the auspices of the U.S.A.F.I. A large number of men have received some mathematical training while in the Armed Forces, and these examinations are planned to help meet the need for some means of providing fair credit and proper placement for these men when they return to collegiate institutions. The examinations are of the multiple choice type; the revised forms prepared by this Subcommitte have been planned for examination periods three hours in length. The selection of material covered by these examinations was based on results of an extensive sampling of the opinions of college departments of mathematics in regard to the content of courses in the considered subjects. These opinions were secured at the suggestion of Professor Tyler, by circulating in June, 1944, a questionnaire prepared by Professor Reid, with the aid of Professor Hart.

"Each of these examinations has been prepared in two forms. One of these forms, referred to as Form A, is the confidential form administered only under safeguards provided by the U.S.A.F.I. The War Department has made arrangements for the Form A of the examinations to be given under the following three conditions: firstly, by the Armed Forces Institute for men and women in service; secondly, by the Veterans Administration for those who seek vocational and educational guidance from one of the Veterans Advisement Centers; thirdly, by the Veterans Testing Service which is being set up on the campus of the University of Chicago by the American Council on Education. Copies of the other form, Form B, of these examinations may be purchased from the American Council on Education by faculty members of educational institutions; orders for these tests should be addressed to Cooperative Test Service, 15 Amsterdam Avenue, New York, N. Y. Some institutions may desire to use results on Form B of the examinations in granting credit for work done with the U.S.A.F.I. If an institution desires to use Form A of one of these examinations in accrediting the work of a given individual, however, application should be made to the Veterans Testing Service, The University of Chicago, 6010 Dorchester Avenue, Chicago 37, Ill. In response to such an application a copy of the examination will be issued to a duly appointed representative of the institution for administration, and subsequent re-

turn of examination and answer sheet to Chicago for scoring and recording.

"In view of the late date of preparation, the forms of these subject examinations prepared by this Subcommittee have not been standardized by the Armed Forces Institute. Both forms A and B of these examinations will be standardized in the near future, however, under a project that is being undertaken jointly by the War Department and Cooperative Test Service of the American Council on Education." [2]

"The procedure of examination construction used by the Subcommittee was as follows:

(a) One member of the committee assumed the responsibility of constructing the examination in a given course;

(b) subsequent to the construction of an examination, two other members served as official critics, going over thoroughly all questions and responses, and offering criticisms and suggestions;

(c) after the member responsible for the construction had made revisions in the light of the criticisms of the official critics, the examination was submitted to the group as a whole for further criticism, and, finally, for approval." [3]

The Evaluation of Achievement in Terms of Local Needs

As stated above norms for the mathematics tests of this series are not yet available, but will be soon. However, the desirability of relating varying degrees of achievement on the tests to the scholastic standards of the local institution cannot be stressed too often. "It is fundamental to the policy of the Armed Forces Institute that there shall be no attempt on the part of the Institute to impose any standards set up by it on the educational institutions of the United States. There is the danger, however, that educational institutions, by uncritical acceptance of norms established by the Institute, will impose upon themselves standards which do not necessarily meet their local needs. In institutions of higher than average scholastic standards this may result in overestimates of the educational status of returning service men and women. Conversely, in institutions serving students of lower than average academic background, underestimates of educational status may result. For institutions of average scholastic standards and average competence of student personnel the published norms may be adequate bases for interpretation, but, ideally, each such institution should determine for itself that this is the case." [4]

Several suggestions are made by the distributors of the test as to the procedure which may be used in local institutions. These will be summarized briefly.

1. The instructors should become thoroughly familiar with each test by taking it themselves and by subsequently analyzing the various parts and items in order to relate these parts to the objectives of their own courses, observe the abilities and skills tested, etc.

2. When the test has been given to a group of students in an institution, it will then be possible to compare the scores of individuals in the group with estimates or measures of their previous knowledge or with the test norms. This will serve the purpose of making future scores on the tests comparable with the standards of the local institutions. It must be remembered, of course, that classes in college at present are not the same sort as we would

[2] W. T. Reid, "Activities of the Committee on Examinations," *The American Mathematical Monthly*, Vol. 52, No. 3 (March 1945), pp. 173–175.

[3] *Ibid.*, p. 175.

[4] United States Armed Forces, op. cit., p. 3.

have in normal times and for that reason may not be typical.

3. If or when the total number of students tested exceeds *one hundred,* it is desirable to convert the raw scores on the tests to local percentile ranks. The percentile rank of any given score is the percentage of students who received scores equal to or less than that score. The use of percentile ranks is subject to the same limitation as No. 2, that is, the group may not be representative.

4. However, it should also be remembered that the tests are made up of various parts which are designed to test the student on proficiency in certain areas of the subject. For example, the college algebra test is made up of five parts.

"Sec. I. Fundamental Operations, Radicals, Exponents, and Linear Equations in One Unknown. 13 items.

Sec. II. Systems of Linear Equations in One and Two Unknowns; Quadratic Equations and Related Topics. 20 items.

Sec. III. Binomial Theorem, Progressions, Variations, and Complex Numbers. 14 items.

Sec. IV. Inequalities and the Theory of Equations. 14 items.

Sec. V. Determinants, Permutations, Combinations, and Probability. 9 items." [5]

Hence, the student's scores on these parts may have much to do with the credit he receives as well as where he is placed in the college classes.

"The institution that recognizes the diagnostic significance of the part scores, that provides for guidance and placement in terms of varying degrees of proficiency within the individual, and offers opportunities of review instruction where placement alone does not solve the individual problem will better meet the needs of the returning service man or woman than the institution centering its attention on the awarding of letter grades." [6]

Conclusions and Suggestions

From this brief discussion, which is based on inadequate information about these tests, it may be useful to state certain conclusions and suggestions.

1. It is apparent that the tests were made hurriedly and probably without some of the standard safeguards which are usually considered necessary in such test construction. For example, due to lack of time, probably, the test items were not tried out with any considerable number of students, if at all. One should expect, therefore, to find that some of the questions will be ambiguous or will not test the particular skill or knowledge which the test makers expected.

2. However, the wide range of contact that the tests and test scores will necessarily have with colleges and college teachers may well serve to stimulate the use of such measuring instruments for ordinary college personnel.

3. It may also suggest other ways of obtaining information which will aid in determining the proper credit and placement for these men.

4. It is very possible that the tests or test scores may be used wrong.

a. Test scores provide only one type of information about the needs, achievements and interests of the individuals. These results form a valuable part of the informational background needed for proper guidance, but only a part.

b. The blind use of norms as standards which should be attained by all has already been referred to. It will be the responsibility of the person interpreting the test results to select and use the most suitable bases for a par-

[5] W. T. Reid, op. cit., p. 175.

[6] United States Armed Forces, op. cit., p. 8.

ticular person or group and to give full weight to various other items which may be important.

c. Many teachers feel that to pass a test in mathematics the student must make at least 70 per cent and also that *every* item should measure something for the large majority of the class. These are serious misconceptions when applied to tests of this sort. Since these tests must cover a wide range of knowledge and ability, they should be so adjusted in difficulty that the least able of all the men who take them will score close to zero, the average student will make about half the possible score and the very best student will just fall short of a perfect score. Since the items of these tests were not pre-tested, it is not likely that any such an ideal will exist.

5. If and when similar tests are used for civilian classes, the use of the test as a kind of abbreviated course of study —as a guide to curriculum content— should be strictly avoided. Tests of this sort are made for the purpose of separating the good students from the poor ones and may or may not contain all the pertinent material for a good course of study.

6. If this wider contact of colleges and college teachers with tests of this sort is to mean a permanently wider use of this type of measuring instrument, care must be taken in the construction of the many tests which will be needed for college mathematics courses. They should be sponsored by a reliable organization which has available time, money and expert statistical advice as well as mathematical knowledge which will be acceptable to the main body of college mathematicians. The present tests were constructed by competent mathematicians appointed by the two leading mathematical societies but they may well prove to be faulty because of lack of time and perhaps lack of the application of well known statistical procedures.

Within a short time it may be possible to give a fuller discussion of these tests and the results obtained from their use. Norms will be determined within the next few months on the basis of the results found by the use of the tests in a selected list of colleges. This should give us some idea of the scores to be expected from regular college students. This will assume, of course, that the classes we now have in college are typical classes. It is hoped that after the tests are given in the spring semester of 1945 it will be possible to present another paper showing the actual results of one or more colleges using the tests and also giving more specific suggestions regarding the possible uses of the mathematics tests for prospective engineering students.

The Use of Audio-Visual Aids in Engineering Instruction

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Last fall a survey was conducted of the engineering schools of the Land Grant Colleges as to what use they were making of teaching aids. The replies were varied. Some said that no use was being made. Others said that they were using teaching aids in almost all courses. Further questions indicated that many of the men replying were not familiar with the aids. Also the replies indicated that many were using the aids without knowing it. It is the purpose of this paper to explain the use of aids in the learning proces, then to list the aids and finally to discuss their use applied to engineering classes.

When a teacher tries to explain a new problem arising in almost any subject, one of his first objectives is to show the connection the component parts of the new problem have with those things with which the student is familiar. For instance in discussing the matter of the location of the center of presure in hydrostatics, the teacher would show:

1st, that the force on a small area is equal to $wyda$ (something that is already known by the student)

2nd, that the moment of this force about the water surface is wy^2da (another item in the student's knowledge)

3rd, that the summation of all of the y^2da's written as $\int wy^2da = wI$ (still another item)

4th, that the total force on the area is $\bar{y}wA$ (still another item)

5th, that the moment of this force, by the laws of mechanics, must be $\bar{y}wA$ multiplied by some distance, or $\bar{y}wAy_e$ (another known item)

6th, that $\bar{y}wAy_e = wI$
This is also known

7th, finally $y_e = \dfrac{wI}{w\bar{y}A}$.

This latter was not known by the student but all steps in its development were. This process of breaking an operation or problem down into its parts may be called differentiation. It is a very important step in learning.

Consequently it is readily seen that the process of putting the parts together so that they make up the entire problem could be called integration. Or to carry on the illustration still further if an engineer was to design a sluice gate on a dam, he would have

to go through the steps first of breaking down the problem, then later putting these parts together so they fit into the picture. In learning to handle any analysis these steps of differentiation and integration must be handled satisfactorily.

To continue with this same idea. If one were to consider the design of a gate of any shape, at any depth in a fluid of any density, his problem, to say the least, would be quite abstract. This is the type one does not give to his beginning students. In fact the teacher tries to be very concrete. He specifically states the gate is of a certain shape, at a certain depth, in a liquid of known density. Why? So that the problem is brought within the range of experiences of the student. In a calculus book used in many engineering schools a few years ago, after the principles of maximum and minimum had been discussed, the next chapter was entitled "The Economical Dimensions of a Coal Bin." That chapter heading caused the book to be put on the black list by many mathematics professors—but to Dalaker and Hartig, the authors, and to their students who had shoveled coal in the cold winters of Minnesota it had real significance. Although the solution called for a bin to be made of wood, the problem was concrete in the experiences of the students.

Now as the student progresses in his study in hydrostatics, he is given problems which are of increasing difficulty. Perhaps one should say they are of more abstraction. It is the instructor's hope, because of the richness of the student's experiences in previous less abstract problems, he will be able to handle the process of differentiation of the abstraction and then to reach a solution by integrating the parts. This is the common way new and difficult material is presented.

How will teaching aids assist in this presentation?

One of the objectives of the audio and visual aids is to enrich the student's experiences. They provide him with the mental experiences, so that he can go through the breaking down or differentiation process first, and then reassembling or integrating the parts, thereby arriving at a solution. A sketch is made on the board to illustrate. Still better would be a picture or drawing; if motion is to be involved, then a picture in motion. Finally to give the student the most intimate contact possible, except as a worker on a job, would be a visit to the job—seeing how, when, where and why the work is done.

Another objective of the aids is to eliminate "verbalism"—the use of words in a manner that their use may be misinterpreted.

We have long used sketches. Perhaps we did not know it was to eliminate verbalism, but we knew that a sketch told a lot. It is a visual aid. It also brings the words of a problem into something that is fairly concrete. It does something else. To draw the sketch one has to become familiar enough with the data so that part of the process of differentiation and integration is done—and the aid has been the means.

Still another function of the audio-visual aids is the problem of motivation. This motivation may be of two types—one creating sufficient interest so that the student wishes to study much more—and the other type showing the disastrous results from failing to follow directions. This latter is well illustrated by the Army film "Keep 'Em Clean." From this film no soldier will

learn a thing about cleaning a gun, but after seeing the film he will want to keep his gun clean.

The motivation produced by the aids is usually novel. The aids are interesting to the student. Concrete results can be shown. Some forms of aids such as demonstration apparatus provide opportunities for the student to manipulate.

The aids provide clarification. The principles of the operation of the valve mechanism of a gas engine are greatly clarified by a cut-away model or a cardboard model. The subject studied may be further clarified, by the use of the proper aids, in that the aid selected may show the relation between the functions of the various parts.

The final objective of the aid is to stimulate further study. This is easily done by the proper selection of the aids. They will show the student where the boundaries of knowledge lie and suggest paths of attack.

The four objectives—(a) to enrich the student's experiences; (b) to eliminate verbalism; (c) to motivate; (d) to stimulate—are very worthy. In the use of some teachers these objectives may or may not be all obtained to almost any degree depending largely upon the carefulness of selection and the use made.

Up to this point no attempt has been made to list all the aids. This was left till the objectives could be set up. One author in his book of "Visualizing the Curriculum," * lists the aids as follows:

A. School journey—inspection trips
B. Museum material
C. Motion pictures
D. Still pictures
E. Graphic materials

* Hoban, Hoban and Zisman.

The Navy has found it advantageous to use the audio and visual aids to a great extent. On one subject they use a 16 mm. motion picture in sound dealing with operation; six film strips covering theory, construction (showing cut away) and maintenance; then a well illustrated operator's manual with large, full-size drawings and finally an instructor's manual showing how to use the material. The variety is such that the instructor can select the aid needed at the time. This is important. Also note that the use of aids does not stop with the movie. The movie is used only to show those things which can best be shown by that medium.

The Navy has used charts and diagrams in many ways. Hundreds are available on diesel engines alone; several hundred on steam engines. The third dimension has been added. Models have glamour. Clear and colored plastics have been used. Means have been provided that make it possible to reduce those things, too large to fit in the classroom, to a small size. Also those things too small to be seen clearly are now magnified. Those things that move can now be seen in motion, as if standing still. A large blackboard globe 24" to 36" in diameter is used in navigation. Lines can be drawn on it. Also a quadrant, showing the inside of a celestial sphere, is available for showing the principles of star shots, etc. All of these and many more that you can think of are definitely aids. They all tend to make the transition from the abstract to the concrete easier by enriching the student's experience, by eliminating useless words, by motivating and by stimulating. Much can be said on the effectiveness of any of these aids.

What, then, is the significance of this business of "audio-visual aids," as

far as our jobs are concerned? What does this mean in teaching engineering? Most of the aids themselves, the blackboard, the map, model, and movie, have been part of our teaching equipment for a long time.

Broadly speaking, two avenues of activity are open to engineering instructors today, both with considerable promise of increments in faster learning, greater interest, and increased understanding on the part of engineering students.

First of these is attention on the part of instructors to the important matter of selecting and using teaching tools to do the best job for them. The teacher's job involves two phases, first to help learn particulars or details, and from these to develop skill in arriving at generalizations, rich and meaningful. To assist a class to arrive at this desirable goal, audio and visual aids can provide some important assistance, in providing a common background of experience, in arousing interest, in enlarging the microscopic, in condensing the gigantic—in making concepts "classroom size," vivid, and real. But the training aid cannot do any of these things by itself. There are a few paramount principles regarding the use of such teaching devices in the lecture room which must be borne in mind to guarantee results.

First: *select with care.* Certain teaching aids will do a specific job better than others. For example, if a study is to be made of a concrete bridge, what method will best serve to present an image of the structure? Probably not a motion picture—no motion is involved. Perhaps a model —therein are three dimensions, true perspective, needing only translation via scale to be reality. Lacking the model, perhaps a picture, drawing, or sketch will serve, or some selection of two or more devices will be chosen. Whatever the items selected, these questions should be answered. Do the aid or aids selected offer the assistance needed so that each member of the class will understand what the instructor wants to teach? Assuming that this can be accomplished, is this the best that can be done? Will it enrich the class's knowledge of our subject? Will it interest them to the degree that they will look further for additional information? In other words, has the instructor selected the best possible means to present this topic or unit to his class, in terms of what they must learn?

Second: *having made a critical selection,* the aids must be presented so that meanings are clear and related to class thinking. Just as one links today's lecture with the closing words of the last class section, so should one introduce the new diagram on the blackboard, or the motion picture to be shown, or the model set up on the demonstration table. Particularly important is this in cases where one is to project pictures whose brilliant image is going to focus class attention on the pictures, not on the voice of the lecturer. Give the aid a chance. Introduce it to the class. Tell them *what* they are going to experience and *why.* Give them a question or two to mull over during presentation, and to answer afterward. Avoid irrelevant material, and plan the timing of introduction to fit the class schedule when meaning will be at its highest.

Third: having used a training aid, *check on the class, the aid, and yourself.* Ask some questions, open a discussion, pop a test, pose a problem, and find out how well your point was carried. This on-the-spot evaluation

is your truest measure of the effectiveness of your instruction—and the means used to accomplish it.

All of this to an already busy teacher sounds like more work. Frankly, it is. On the other hand, it is not much more, after the first few tries at breaking away from a strict lecture-problem-quiz routine. Teachers, like the pure in heart, will find their ultimate reward only in heaven, but you can collect some advance payments on earth with livelier classes, more interested students, and people coming to you with thanks for "showing me what you are talking about."

The second of the things which the engineering teacher can do to improve his command of a stock of teaching aids available to him at the time they will do the most good is a purely practical one. Through his own department, through cooperative action among college departments, by interchange of ideas, materials and facilities among institutions, and by promotion of development of teaching materials by professional associations, teachers can contribute to the accumulation of source-pools of teaching materials at their own and other institutions.

Already in existence at many colleges, but behind in accomplishment in comparison to many progressive public schools, are full-fledged departments whose job it is to provide instructors with the help they need to keep their instruction on a vital, progressive plane. A logical adjunct to the professional library is the professional "Instructor Services Department." Here is collected the files of pictures (thousands of them in some schools), mounted for easy use, or photographed as lantern slides and slide films. Here is a motion picture library, a collection of models, posters, graphs, charts, dioramas, synthetic training devices. Here, too, is a production unit for producing needed new material, new pictures, drawings, schematics, in short—here is the institutional center which matches the book collection which forms the basis for lecture notes, different from that institutional service only in its stock in trade. Both are dedicated to the same idea—to provide ideas, information, and illustrations to make teaching effective, and thereby meaningful to pupil and instructor alike.

No objection to publication for security reasons.

Refresher Courses, A Phase of Continuation-Education

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One of the immediate problems that is just around the corner for us in engineering education is the formulation and teaching of a type of course that has been designated frequently as a "refresher course." The current demand for such a course, as well as the name, seems to have grown out of the war. Large numbers of engineering graduates were called to military service on the day of graduation; some received their diplomas in absentia. All of these men went to war before they had had opportunities to take positions as college graduates usually do at commencement time. An older group of engineers left their positions and took military leave to enter the armed forces. In the minds of many men in both groups there is a common feeling, namely, that their work in the war has not been of a nature that demands the use of engineering skills which would enable them to "keep up" in their professional fields, and that they know nothing, or very little, about the wartime advances in technology. Naturally, this feeling makes some of them a little worried, even "panicky," as the day draws nearer when they will return to civilian life to resume the building of their professional careers.

Before discussing the details of the contents of some of these "refresher courses" I would like to point out that they are a phase of a much larger movement, one that has been growing steadily in importance and magnitude. I refer to adult education, or continuation-education, as it is sometimes more accurately designated. There are many types of such programs extending through the entire system of organized education from the public schools to the universities. Other areas are covered by public and private clubs, by governmental agencies, and by professional societies and industrial companies. Doubtless, improvement in the media by which information can be transmitted, in the written and spoken form and with visual aids, has had an important effect in this development.

Although all of these programs are important and make significant contributions to the education of adults in many areas, they do not furnish technical education to engineers at the level which the engineering graduate requires. Perhaps an example will make that difference clearer. To college and university people the best known adult education programs are those that are handled through the extension departments of the colleges and universities. Of these the work in agricultural and home economics extension has a very broad coverage. Their aim, generally, is to aid the citizens in matters of everyday living: to help them grow bigger crops or raise better cows, or to bake better cakes, or to use electricity. In

some states there are extension and short courses for sewage and water plant operators. These are practical programs pitched to meet the needs and abilities of people who till the soil or make homes. They are not designed for and in many instances would not appeal to the college or university graduate in the professional fields.

The expanded continuation-education program of the future will have a wider coverage than the present one has. It will offer courses in broad or general education, and courses of a specific technical nature for the professionally trained man. Congress has already recognized the need for Federal participation in extension programs in areas other than agriculture and home economics and has proposed a measure entitled College and University General Extension Act, S1670, 78th Congress. The offering of such programs by the colleges will in no way relieve the individual professional man of his responsibility to keep up in his field. It does recognize that developments in those professional fields, such as engineering, medicine and law, have been so numerous and so rapid that the individual practitioner cannot assimilate the available new knowledge which he needs without aid. It recognizes further that the public welfare requires that the professional man must have command of these most recent developments in his field so that he may render the most effective service to the public. This statement applies with equal weight to continuation studies in general education, without which the professionally trained man finds himself only partly effective.

Heretofore, the responsibility for bringing new knowledge and new techniques to the attention and use of practitioners in the various professional fields has been shared by the organized professional bodies and governmental agencies and educational institutions. For example, the various medical societies have sponsored clinics and schools of instruction; engineering societies in cooperation with industrial companies have held short courses at convenient places; all of these organizations have published a large amount of technical literature. Something is needed to extend and expand these very worthwhile efforts. Large numbers of people who should have the information do not receive it. Who is in a better position to disseminate what is needed than the educational institutions that gave these professional men their first training? They can do this through the medium of instruction on the campus, through in-service training in person or by radio, by clinics, by short courses, or by other methods.

It seems reasonable that the "refresher courses" may be an important beginning phase of this broad program of continuation-education in engineering. At the moment the nature and contents of these suggested courses are not clear because the men who would be expected to take them have only hazy notions and plans for the postwar period. All believe that they will need some kind of a review; most would like to take advantage of the educational opportunity offered by the "G.I. bill." Those who went from college to the armed forces think that it may be smarter to take a job if one is available on the day of their release because they fear jobs may not be so plentiful later. Those who are on military leave from jobs, to which they expect to return, do not know what the attitude of their companies would be toward a delayed return.

Nevertheless, in spite of these un-

certainties, we who will be responsible for the organization and teaching of the courses must go ahead with their preparation so that we will be ready with something when the men begin to return. We are thinking now of men who have graduated, or have completed certain course work, who wish to regain knowledge and skills lost through lack of use, to catch up on recent developments in their fields, as well as to study courses of a general nature. For many of the suggestions which follow I am indebted to Iowa State College Civil Engineering alumni who have written me from the battlefields of Europe and the Pacific. Doubtless, those who remain in Europe will have time now to think about these matters and will have other useful suggestions for the course content and the method of presentation.

To find a good job promptly after discharge will be one of the first desires of all men who were able to complete their college work and obtain degrees before they entered the military service. To facilitate this it will be desirable for all companies who expect to employ any of the returning engineers to have a well organized and effective employment and personnel service. Every one of these returning engineers should arrange interviews with the representatives of some companies where, he thinks, he would like to work. He would be wise if he did this interviewing and visiting by personal calls at the offices, plants or construction projects of the prospective employers during his leave period. Several results would come from these interviews. First, and most important, the young man could get a job that would fit his needs and abilities. Second, he and his future employer would decide whether he should begin work immediately or return to college. Third, knowing the type of work that he is to do later the man will be able to select some of his "refresher courses" with an eye to their specific application and usefulness.

The program that he follows at college should, in the beginning at least, be somewhat lighter both in credit hours and in number of courses than the usual student load. He will be "rusty"; he will be seeking a thorough understanding; and he will want time to pursue interesting sidelines and related matters. Moreover, the "refresher courses" should be designed for this specific purpose and the objectives should be clearly defined and stated. The teaching methods should be those that are recognized as satisfactory and adequate for the purpose and the teachers should be sympathetic, able and thorough. Probably the use of small sections with plenty of opportunity for student teacher contact through recitations, laboratories and conferences will bring the best results.

Possibly the word "refresher" is misleading because it suggests a limited program. A broader term such as adult or continuation-education would come nearer to expressing the purpose. A good deal of the course work will be over ground that was covered by the student when he was earning his undergraduate degree. That could be designated "refresher." Some in the professional and technical area will be that which brings him up to date on latest developments in his field. That might be called "continuation." In addition to these, there are other important courses which should be stressed, which the returning student may be inclined to slight or pass by entirely. These are the courses in the area of general education, frequently designated the humanistic-social stu

in the literature of engineering education. He will need some of the knowledge in economics, history, government, psychology, sociology and others to make him a useful and effective citizen as well as a better engineer.

To illustrate the type of program, let us assume that our returning civil engineering graduates will choose to study either a group of courses for a short time, say one quarter or one semester, or a different group for an entire year. From the standpoint of flexibility and adaptability to changes in plans of the students the first term should be the same for all—those who intend to remain for one term and those who intend to stay longer. Whether or not the short program will be a separate unit from the first term of the longer program will depend upon two factors: the number of men who will get what they want in one term, and the clearness with which the needs of the two groups can be differentiated. For this discussion we will consider them as separate and independent units.

For the single-term unit our students will take five three-credit courses and will cover the following material: Course I, a review of mathematics extending from algebra through calculus, with emphasis on the use and typical applications of mathematics to problems in the student's field. Course II, course III and couse IV will be, respectively, structures; transportation; hydrology, water and sewerage. In each instance the major attention will be given to the application of fundamental principles to the solution of problems, with secondary attention given to special techniques and methods. Course V will be a combination of economics, history and sociology, in which an attempt should be made to bring out the inter-relationship and inter-dependence of the social, economic and physical forces that the engineer must deal with.

We will assume that our long program will cover an academic year of three quarters or two semesters, and that in each quarter or semester there will be five three-credit courses. The quarter system will be used to illustrate the sequence of courses. During the first quarter the students will have the following courses: Course I, a review of mathematics similar to that of the short program. Course II, a review of mechanics from statics through hydraulics. Course III, written and spoken English. Course IV, a review of physical sciences, principally chemistry and physics with some geology, the primary emphasis being on the uses of these sciences in the work of the civil engineer. Course V, a combined social science course such as described for the short program.

In the second quarter they will take work in the major fields of civil engineering. It is my belief that they would be wise to do some reviewing in all of the fields, leaving specialization until the last quarter because they are at the beginning of their careers which, sooner than they expect, may require knowledge and skills outside of what today may seem to be their ultimate needs.

The courses of this second quarter will be designated with numbers from VI to X as follows: Course VI will be soil engineering in which the students will learn the general principles that may be applied to all situations, and in particular those that are used in the design of road and airport surfaces and in foundations. Course VII is transportation engineering in which the major attention is given to the inter-relationship of the various forms of transportation and to principles of planning, layout, traffic, safety, and

economic costs, with design of the roadbed and surface deferred to a later course for those who wish to do more in this field. Course VIII, structural engineering, will be a rapid review of the use of principles in the analysis and functional design of structures in concrete, steel and timber, including indeterminate structures. Course IX we will designate hydrology and water utilization and control. It is included here, because of the basic importance of this knowledge to the engineer as a citizen and as a man seeking a job on river improvement, reclamation, irrigation, power, water supply, and similar projects. Course X, engineering economy, will cover the relative costs of alternative ways of doing jobs in typical situations that arise in practice, and the related elements of quantity estimates and construction costs.

In the third and final term of this sequence the students will round out their programs in five courses, numbers XI to XV, which they will select. I would suggest that the freedom of selection be limited to this extent, namely that at least two of the courses be in the humanistic-social field. To illustrate, let course XI be engineering reports which would include the collection, assembly and interpretation of data and the writing of one or more complete reports. Course XII could be labor and industrial relations which would deal with the relations of employer and employee and matters of public policy such as labor legislation and social insurance.

The other three courses of this third term might be a group of closely integrated courses in which each man seeks to push as far as he can in his specialty, or they might be less closely related technical courses. For example, the man with a major interest in the highway field might choose course XIII in highway materials; course XIV in highway safety and traffic control; and course XV in highway and airport surfaces. The man interested in sanitary engineering and public health could have for course XIII suitably arranged material in sanitary chemistry; course XIV could cover municipal and rural sanitation; and course XV would cover the planning, design and construction of water and sewerage works.

The man who chooses not to specialize narrowly during his last term should have a variety of courses to choose from. In addition to those mentioned the list might include the following: structural design and detailing, railway engineering, photogrammetry, similarly organized courses in other engineering departments for which he is adequately prepared, business law, public administration, world history, psychology, meteorology and climatology, and others.

Enough has been written here to indicate the purpose, direction and scope of "refresher courses." As the time which the man spends on such work is extended beyond two quarters we see that the differences between the objectives and methods of teaching the "refresher courses" and objectives and methods of teaching the regular courses become minor. This brings us again to the broad aspects of this problem which were raised earlier in our discussion, namely, the need of engineers for adult or continuation-education, both technical and cultural, and the engineering schools' responsibility to provide that education. Teachers of engineering may have an opportunity here to render a broad and useful service and to exert a major influence on the professional and technical growth of engineers.

An Introductory Course in Administration for Engineers

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Based upon experience and statistical studies, engineering educators and practitioners agree that a majority of graduates in all branches of the profession are concerned as much with administration and management as with technology. A few engineers enter some phase of administration immediately upon graduation but more often the earlier working years are devoted to relatively technical duties. However, it is estimated that ten years after leaving college two-thirds of engineering graduates occupy positions which are primarily administrative in nature. The Report of the Committee on Engineering Education After the War [1] voices the need for studies in operation and management, and the Engineers' Council for Professional Development has approved this Report.

While many engineers are engaged in duties that combine technical viewpoints with business, industrial, and governmental management, most of them have had to pick up their knowledge of administration by trial and error after graduation. Such a process is too difficult and too costly for young engineers who have not a ready aptitude for acquiring power in that way. These the colleges can help, with resultant benefit to industry.

The foregoing facts have long been recognized and several methods of meeting the engineer's need for college work in this field are now in effect as follows. It will be noted that limited use is made of the first four of these methods.

1. A very few engineers undertake graduate study in business administration.

2. The Twelfth Annual Report of E.C.P.D. for the year ending September 30, 1944, lists only 21 curricula in administrative, management, or industrial engineering out of a total of 499 accredited curricula in all types of engineering which are offered at 133 institutions where one or more curricula have been accredited.

3. The Report also lists 10 similar options which have been approved in connection with other accredited curricula.

4. Brief attention to specialized applications of administration is but rarely included in regular engineering courses.

5. Often engineering colleges accept a few of a great variety of specialized industrial and business courses, some of which are taught by engineers and some in business administration divisions of the institutions.

6. Many engineering curricula require, or offer as elective, courses

[1] The JOURNAL OF ENGINEERING EDUCATION, Vol. 34, May, 1944, pp. 591–592.

which may be termed an introduction to engineering administration or management, although often titled otherwise. These courses have similar objectives but great variety of approach, content, text books, and course materials. Frequently they emphasize a single phase of administration.

This article describes briefly an introductory course appropriate to the fifth and sixth methods immediately preceding. To become well trained in engineering is time-consuming, and consequently a thorough education in administration is seldom practicable. A good available substitute for the latter may be provided by a brief but comprehensive course, devoted partly to acquiring a broad acquaintance with the field and partly to those definite applications most frequently encountered by the engineer, interest in the former being stimulated by the latter. It is believed that a comprehensive course generally is preferable to a single specialized course, and that often it may supplement specialized courses.

If taught to mature students in the upper years of the curricula, such condensed material can be assimilated with great profit to the practicing engineer and to economic welfare in general. Educationally, this is but another of the current efforts to broaden highly specialized curricula.

This introductory course attempts to familiarize the young engineer with the major departments and functions of large private and public enterprises, and thus to emphasize that engineering is only one of these functions, usually essential but often of lesser importance from the viewpoint of the private or governmental administrator. The technical man must develop this concept so that as an engineer he may cooperate effectively with other departments of his organization, so that he may adapt the engineering method of attack to the solution of problems in the non-technical department in which he may be employed, or so that he may look forward to a position in general administration.

Doubtless each instructor and each student will place varying emphasis upon different phases of the outline which follows:

An Introduction to Administration for Engineers

(Three to six semester credits)

Introduction

(About one-tenth of the course)

The Engineer's Relation to Administration.
Administration as Affected by Social, Political, and Economic Trends.
The Expanding Need for Engineer-Administrators.

Part I. The Non-Engineering Functions of an Organization

(About three-tenths of the course)

Promotion.
Finance.
Organization.
Management.
Marketing and Sales.
Advertising.
Purchasing.
Personnel and Labor Relations.
Public Relations.
Accounting and Auditing.

Part II. The Semi-Engineering Functions of an Organization

(About three-tenths of the course)

Cost Accounting and Statistical Control.
Estimating.

Valuation, Taxation, and Rate Structure.
Engineering Economy.
Time and Motion Study.
Safety and Insurance.
Industrial Technologic Research.

PART III. CASES, PROBLEMS, AND PROJECTS

(About three-tenths of the course)

PART IV. BIBLIOGRAPHY

The material outlined above will attain its full value if enriched by assigned current reading, discussion, and work with concrete situations. Thus augmented, the course may be expected to develop in the student an interest in administration, an acquaintance with the more important departmental functions of industrial enterprise, and that familiarity with terminology without which progress in administration is impossible.

For the instructor, the outline is simply a basis on which some subjects may be contracted or expanded and to which others may be added as appears necessary. For the student, it provides a reference and a foundation upon which he can build further knowledge and practice, and from which he may depart in quest of specialized knowledge from authoritative sources.

It must be emphasized that a reading or lecture presentation will not suffice. The student must participate in finding and selecting authoritative materials, in raising questions, in working problems, in making decisions, in studying current developments, and above all in sensing applications to his proposed career. This last objective may be partly attained by having the student report on the particular organization in which he hopes to establish himself.

It is essential that the instructor have a mature and well-rounded background in administration from the engineering viewpoint. Often he acts as group discussion leader rather than as teacher.

Where time permits, certain subjects may be omitted from the introductory course and taught in separate courses, but without a broad introduction the student acquires from these separate courses only additional semitechnical tools while still lacking a comprehensive view of enterprise as a whole.

The conclusions here presented result from the writer's use of various presentations in teaching this course since World War I.

To summarize: The need of engineers for education in administration has long been recognized by practitioners and educators; few engineers receive broad instruction in this field; a satisfactory introduction can be given in a single course if only limited time is available; and a uniformly favorable reaction is to be anticipated from employers, alumni, and students. Specific subjects may be taught in additional separate courses.

Returns from a Questionnaire on the Accelerated Program

By J. W. STEWART

Assistant Professor of Mining Engineering, University of Illinois

The college of engineering at the University of Illinois is operating on the wartime accelerated engineering program. In anticipation of the conclusion of the present world conflict, the College of Engineering Committee on Policy and Development recently appointed a subcommittee to make a study of the necessity and desirability of a postwar continuation of the present wartime program.

Desiring factual information regarding engineering student and faculty attitudes toward a postwar accelerated program, the subcommittee devised and sent out the questionnaires indicated below. The student questionnaire was sent to all students in the College of Engineering of sophomore standing or higher. The faculty questionnaire was sent to all College of Engineering staff members on board-of-trustee appointment. In order to obtain a sample of faculty opinion elsewhere, a limited number of faculty questionnaires was sent to engineering faculty members at various other American colleges and universities. This latter procedure enabled the subcommittee to compare faculty opinion at the University of Illinois with that existing at similar educational institutions.

The returned questionnaires were scored and a comprehensive tabulation was made of the data obtained. Lastly, a report making recommendations relative to a postwar continuation of the accelerated program at the University of Illinois was written by the subcommittee and rendered to the College of Engineering Committee on Policy and Development. This report is not included here because it is felt to be of local interest only.

Below are given the following in the order stated:

(1) The explanatory sheet which accompanied each questionnaire sent out.
(2) The faculty questionnaire.
(3) The student questionnaire (in part).
(4) Tabulated returns from the questionnaires.
(5) Comments.

April 3, 1943

University of Illinois

THE COLLEGE OF ENGINEERING COMMITTEE ON COLLEGE POLICY AND DEVELOPMENT

through its

SUBCOMMITTEE ON THE ACCELERATED PROGRAM

requests your careful consideration of the accompanying QUESTIONNAIRE. The Subcommittee has been designated as the body to study at first hand the possible need for

the Accelerated Program, in connection with the overall future program of the College of Engineering. The final Committee report will be submitted to the Faculty of the College of Enginering for consideration and action.

THE ACCELERATED PROGRAM

The *Accelerated Program* implies the incorporation of *three* 16-week semesters (or *four* 12-week quarters) of instruction in each calendar year, instead of the conventional two-semester (or three-quarter) year as in the past. It means that a student can complete the usual *four-year* curriculum in something like *three years*, depending upon vacation periods; or perhaps complete a five-year program in the conventional four-year period.

In order to determine reaction to the Accelerated Program, the Subcommittee has formulated the accompanying QUESTIONNAIRE.

It is Requested that You Answer Promptly!

THE FACULTY QUESTIONNAIRE

Your Name .....

Address .....

.....

INDICATE YOUR STATUS (check):

(*a*) Faculty (at Illinois) .....( )

(*b*) Faculty (elsewhere) .....( )

INDICATE YOUR PERSONAL PREFERENCE (check one only):

1. I FAVOR the Accelerated Program as a permanent policy for the College of Engineering in the postwar period .....( )

2. I FAVOR the Accelerated Program *only* for such a postwar period as will meet the needs of returning veterans of World War II .....( )

3. I DO NOT FAVOR the Accelerated Program but favor an immediate postwar return to the conventional four-year program .....( )

The Reasons for My Preference Are:

(*a*) The conventional four-year curriculum, leading to the B.S. degree in engineering, can effectively be completed in less than four calendar years .....( )

(*b*) In the light of modern technical advances, a five-year curriculum is necessary, and such a curriculum can readily be completed in four years on the accelerated program .....( )

(*c*) The summer vacation periods of the conventional four-year program are a waste of time .....( )

(*d*) The summer vacation periods of the conventional four-year program are desirable for students, in order that they may have opportunity to obtain needed experience in industry and engineering .....( )

(*e*) The conventional summer vacation periods are necessary for students, in order that they may have opportunity to earn needed funds to defray school expenses .....( )

(*f*) The conventional summer vacation periods are necessary for students, in order that they may have a proper mental rest period .....( )

(*g*) The lessened maturity of graduates of the Accelerated Program is undesirable .....( )

(*h*) The Accelerated Program would result in added cost per year to the student .....( )

(*i*) The conventional summer vacation periods are desirable for the faculty, in order to obtain industrial and engineering experience, or to do full-time research or writing .....( )

(*j*) The conventional summer vacation periods are desirable for the faculty, in order that they may have a proper rest period .....( )

(*k*) The Accelerated Program would make for more effective utilization of the faculty, with resulting increase in salary level .....( )

(*m*) The Accelerated Program would result in more effective utilization of the physical plant .....( )

Other Reasons

(*n*)

(*o*)

Subcommittee on the Accelerated Program
C. D. GREFFE (Mechanical Eng.)
H. A. NYE (Dept. of Physics)
C. E. SKRODER (Electrical Eng.)
J. W. STEWART, *Chairman* (Min. and Met. Eng.)
JAMISON VAWTER (Civil Eng.)

THE STUDENT QUESTIONNAIRE

Your Name .....
Address .....
.....

INDICATE YOUR STATUS (check):

(*a*) Student Veteran .....(So.) (Jr.) (Sr.)
(*b*) Civilian Student .....(So.) (Jr.) (Sr.)
(*c*) V-12 Student .....(So.) (Jr.) (Sr.)

INDICATE YOUR PERSONAL PREFERENCE (check one only):

(Same as on the Faculty Questionnaire.)

The Reasons for My Preference Are:

(Same as on the Faculty Questionnaire except that Reasons *i*, *j*, *k*, and *m* are omitted. It was thought that these reasons pertained largely to the faculty.)

Subcommittee on the Accelerated Program
C. D. GREFFE (Mechanical Eng.)
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JAMISON VAWTER (Civil Eng.)

TALLY—FACULTY QUESTIONNAIRE

Faculty Status	Total	Preference			Reasons											
		1	2	3	a	b	c	d	e	f	g	h	i	j	k	m
Illinois	108	9	67	32	6	9	1	87	78	56	60	26	85	49	10	13
Elsewhere	23	1	13	9	1	1	0	22	17	14	16	5	22	11	0	2
Total	131	10	80	41	7	10	1	109	95	70	76	31	107	60	10	15

TALLY—STUDENT QUESTIONNAIRE

Student Status		Total	Preference			Reasons							
			1	2	3	a	b	c	d	e	f	g	h
Veteran	So.	8	1	6	1	3	0	2	2	4	3	2	1
	Jr.	10	4	4	2	1	1	2	1	1	1	1	1
	Sr.	2	0	1	1	0	0	0	1	2	1	0	0
	Total	20	5	11	4	4	1	4	4	7	5	3	2
Civilian	So.	27	7	8	12	5	3	1	16	11	12	6	2
	Jr.	28	6	12	10	9	3	1	18	18	16	8	7
	Sr.	33	5	14	14	2	3	0	22	19	18	13	4
	Total	88	18	34	36	16	9	2	56	48	46	27	13
V-12	So.	32	6	20	6	5	3	2	19	23	20	2	1
	Jr.	107	17	35	55	9	10	5	77	72	59	19	17
	Sr.	92	5	40	47	5	4	1	75	71	56	29	8
	Total	231	28	95	108	19	17	8	171	166	135	50	26
Total		339	51	140	148	39	27	14	231	221	186	80	41

COMMENTS

Recognizing that a vote for either the second or third preference, as stated in the questionnaires, is a vote against a permanent continuation of the present accelerated program, it is obvious that both the engineering faculty and students at the University of Illinois are opposed to an accelerated program as a permanent educational policy. A study of the questionnaire tallysheet reveals the reasons for this attitude.

The chief reasons given by the faculty for opposing a permanently accelerated program follow in the order of their apparent importance. It is interesting to note the close correlation existing between engineering faculty opinion at the University of Ilinois and corresponding faculty opinion at similar institutions:

(*d*) The summer vacation periods of the conventional four-year program are desirable for students in order that they may have opportunity to obtain

needed experience in industry and engineering.

(*i*) The conventional summer vacation periods are desirable for the faculty in order to obtain industrial and engineering experience, or to do full-time research or writing.

(*e*) The conventional summer vacation periods are necessary for students in order that they may have opportunity to earn needed funds to defray school expenses.

(*g*) The lessened maturity of graduates of the accelerated program is undesirable.

(*f*) The conventional summer vacation periods are necessary for students in order that they may have a proper mental rest period.

(*j*) The conventional summer vacation periods are desirable for the faculty in order that they may have a proper rest period.

The chief reasons given by the students for opposing a permanently accelerated program follow. It is noted that the student questionnaire did not include any reference to matters which were thought to be more specifically the concern of the faculty.

(*d*) The summer vacation periods of the conventional four-year program are desirable for students in order that they may have opportunity to obtain needed experience in industry and engineering.

(*e*) The conventional summer vacation periods are necessary for students in order that they may have opportunity to earn needed funds to defray school expenses.

(*f*) The conventional summer vacation periods are necessary for students in order that they may have a proper mental rest period.

(*g*) The lessened maturity of graduates of the accelerated program is undesirable.

The Prony Brake

By LT. COL. P. M. HONNELL
U. S. Military Academy

Baron de Prony's friction brake[1] sometimes exhibits undesirable characteristics, the most annoying being the unsteadiness of the mean load developed and the high-frequency chatter of the brake shoe. This leads to erratic —sometimes unreadable—deflections of the indicating needle of the scale utilized to measure the reaction force on the torque arm. If, in addition to the needle vibration, the brake loading is not smoothly adjustable but is instead restricted to a small percentage of the total available motion of the control screw, and the zero reading of the brake is not easily nor accurately measurable, then the device is indeed not very useful and the students' subsequent distinterest in the test method is justly founded.

Nevertheless, the prony brake can be a very useful pedagogical device for the simplest physical illustration of the mathematical concepts of torque, brake horsepower, and the conversion of mechanical energy to heat energy. This is its real and fundamental usefulness in introductory courses in the undergraduate laboratory; the utility of the device for measuring the external characteristics of a prime-mover is of secondary importance.

The purpose of this note is to describe a prony brake design which minimizes brake chatter, provides steady loads, and when used with a simple mechanical vibration filter, completely eliminates high-frequency vibrations from the indicating needle of the measuring scale.

The Prony Brake

A very satisfactory prony brake evolved by extensive experimentation, which differs from the usual construction in important details to be described, is illustrated in Fig. 1A. Its main elements are a brake shoe and light-weight torque arm, a scale suspended from a vibration-free support, and a mechanical vibration filter connecting the torque arm to the scale. The brake shoe is constructed of four pieces of maple, shaped as shown in Fig. 1B and bolted together. The torque arm consists of a length of light ¾-inch conduit with a two-foot lever arm, filled with sand to introduce some internal hysteresis. Five small pieces of maple with rounded edges, and held in exact parallelism to the shaft by flexible chains, complete the lower portion of the braking surface.

The weight distribution of the shoe and position of the torque arm were developed by experiment; many other combinations were tried, including one with the entire weight below the shaft (that is, the brake illustrated turned upside-down), but none was as satis-

[1] Prony, Gaspard Clair François Marie Riche, Baron de (1755–1839); French engineer, mathematician and physicist of the Napoleonic era.

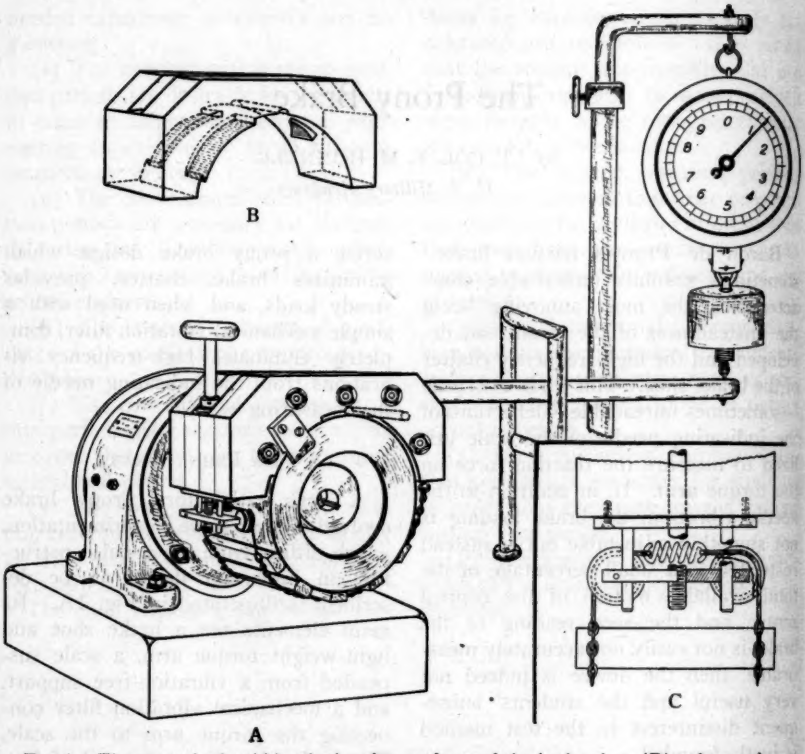


FIG. 1. The prony brake (A); the bearing surfaces of the brake shoe (B); the tension-equalizing spring (C).

factory as the brake illustrated. It is interesting to note that this is substantially the same weight distribution and torque arm arrangement utilized from early days.

The friction-operated prony brake depends primarily for its successful operation on the constancy of the coefficient of dynamic friction of the rubbing surfaces. Many factors affect this coefficient, among which are the materials of the rubbing surfaces, their shape and smoothness, the warping of the brake surface due to temperature changes resulting from the braking action, and the nature of the lubrication of the surfaces. At the outset, it may be pointed out that the use of automobile brake lining for the braking surface is unsatisfactory for the slightest amount of water on the lining will invariably cause chattering and unsteadiness of the mean load. The unsatisfactory operation of wet automobile brakes is sufficient proof of this point. However, the friction brake requires forced water cooling, and constant wetting of the rubbing surfaces must be considered as more than likely in the hands of students. The brake illustrated therefore dispenses entirely with brake lining, and instead makes use of

hard maple for all the friction surfaces. Finally the brake shoe and the brake drum are lubricated with machine oil, which produces very smooth bearing surfaces practically immune to the effect of water.

Although a brake drum may be accurately machined and ground true on its shaft mounting at room temperature, it is inevitable that the drum surface will become somewhat warped at the elevated temperatures existing during the dissipation of mechanical energy. To insure that the brake shoe will always ride on the drum without a tendency to slide off, the brake shoe bears only on the three small surfaces, shown in Fig 1B. Note that the two rear surfaces bear on the edges of the drum, and that the forward surface bears on the center line of the drum. Thus, when the brake drum assumes a warped contour due to the unequal expansion of its central web and rims, the three-point bearing surfaces permit the brake to continue to ride on center.

Another important feature of the brake is the equalization of the tension on the two chains supporting the five maple friction blocks under the brake drum, because this minimizes any tendency to chattering of the brake, and the resulting whipping action of the torque arm. This self-equalizing action is accomplished by the expedient shown in Fig. 1C. The five maple friction strips are evenly spaced and permanently fastened to two flexible chains (steel cables are unsatisfactory). The chains are connected to hooks on the brake shoe under the torque arm, and their other extremities are connected to flexible steel cables which run over a pair of pulleys; a coil spring connecting the two ends of the flexible cables automatically equalizes the tension on the two chains. This in turn equalizes the pressure on the five friction strips.

The loading of the brake may be varied by adjusting the position of the arm carrying the two cable wheels relative to the heel of the brake shoe. This position of the arm depends upon the handwheel and screw thread arrangement shown in Fig. 1C. Not only is the braking tension self-equalized by this design, but the precise and uniform adjustment of the brake loading as a function of the adjusting wheel rotation is simultaneously achieved. This feature permits the brake loading to exact values, as indicated by the scale, to be easily and smoothly achieved.

Zero Reading

The zero reading of the scale, attributable to the unbalance in the brake caused by the weight of the torque arm, is measured by releasing the adjusting wheel until the maple friction strips are free of the brake drum. A ¼" round brass rod is then placed in the half-round slot on the brake shoe, as shown dotted in Fig. 1A. This lifts the brake shoe from the drum and provides a balancing surface. The associated scale then indicates the initial or zero reading of the brake. This zero reading is of the order of 1½ pounds and will consistently repeat with less than 5 per cent variation.

Motor Mounting

It is clear that a vibration-free prony brake must have a brake drum which, when mounted on the prime mover or motor shaft, has a true cylindrical surface and is dynamically balanced. It is not so evident that the motor mounting should be absolutely rigid. A wooden box-like stand (such as frequently used) will often have sufficient

flexibility to impair the operation of an otherwise satisfactory brake. This is due to the resonant modes of vibration of the motor as a whole which will appear as a shaft whirl. The vibrational modes may be initiated by the brake chatter, or the unbalanced frictional forces acting on the brake drum, causing a pseudo-gyroscopic effect discussed by Den Hartog.[2] For best results, the motor should be solidly mounted on a heavy concrete foundation; in any event the mounting must be rigid.

Mechanical Vibration Filter

The prony brake design described above leads to a smoothly adjustable steady-loading device with a minimum of vibration or chatter. The irreducible minimum brake vibration still remaining may be of the order of $\pm$ 5 to $\pm$ 10 thousandths of an inch displacement at the extremity of the torque arm, and results partly from slight variations in the motor torque. In an electric motor, for example, this may be caused by the armature slots which produce spatial variations of the magnetic field in the air gaps, and which are reflected into the system as a superimposed variable component in the motor torque.

Due to the multiplying factor of the linkage mechanism of the scale, this small vibration of the torque arm may produce a needle vibration with a maximum deflection of $\pm$ 1/16 pound on a scale reading 10 pounds per revolution of the pointer. This residual vibration can be completely isolated by means of a mechanical vibration filter interposed between the scale and the extremity of the torque arm. The filter effectively isolates the scale from the vibrations and makes possible exact readings of the reaction forces on the torque arm. An incidental added advantage is that the rapid wear of the scale linkage due to the vibration is eliminated.

[2]Den Hartog, "Mechanical Vibrations," McGraw-Hill, 1935, pp. 300–302 and pp. 338–339.

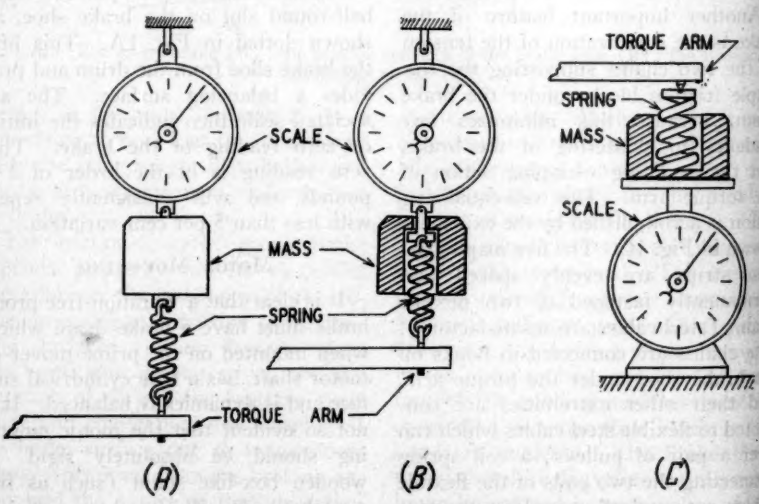


Fig. 2. The low-pass mechanical vibration filter.

The mechanical vibration filter, illustrated in Fig. 2, is a simple device which passes the zero-frequency component or direct pull of the torque arm unchanged in magnitude, but greatly attenuates the relatively higher-frequency vibrations. It consists of a mass suspended directly from the scale, connected to the torque arm through a spring as shown in Fig. 2A. In order to reduce space requirements, the spring may be mounted within a recess in the mass as shown in Fig. 2B. If used with a platform scale, the arrangement shown in Fig. 2C may be equally satisfactory.

In order to obtain a maximum effectiveness in attenuating the vibrations, the mass should be large and the spring weak. As a specific example, a suitable design for a 5 hp. brake with a two-foot torque arm is a weight of 10 pounds and a spring requiring 10 pounds pull per inch extension.

The mass will of course produce an initial deflection of the scale, and the latter must have sufficient capacity to support the mass and the force exerted by the torque arm. The initial reading of the scale may be eliminated, if desired, by readjustment of the indicating needle of the scale to zero; the initial deflection may not be apparent if the dial is calibrated from 0 to 10 pounds and the maximum scale capacity is some multiple of this figure, provided the mass is carefully adjusted to 10 pounds weight; or finally, the initial deflection may be lumped with the unbalanced weight of the brake and determined as a net "zero reading" of the scale.

For the highest accuracy, the torque arm should remain in a horizontal position for all readings, but this is inconvenient in practice. A 5 hp., 1,200 r.p.m. motor, for example, will exert about 11 pounds force at full load on the scale of the prony brake mentioned above. A scale with one inch deflection for 10 pounds would therefore extend 1.1 inches, and the vibration filter spring would deflect a like amount. Thus a total displacement of about 2.2 inches would result between the no-load and full-load positions of the torque arm. Since the maximum error from neglect of this displacement is only a few per cent, it may be expedient to neglect it for light loads and to arrange the brake so that the torque arm will be horizontal at full loads, where the minimum errors are desirable.

Conclusion

The prony brake described above operates smoothly, is easily and precisely adjustable for loading and provides scale readings devoid of any trace of vibrations. Although a friction device, it is remarkably independent of shaft angular velocity and will provide the same dynamic braking within $\pm$ 5 per cent for a motor speed change of $\pm$ 50 per cent.

The mechanical vibration filter can, of course, be used with any type of prony brake. Two precautions must, however, be observed. In the first place, the scale must not only be isolated from the torque-arm vibrations by the mechanical filter, but the support for the scale must likewise be free of vibrations. Secondly, the vibration filter (being a low-pass network) will attenuate only the high-frequency chatter vibrations of the torque arm and cannot compensate for the general unsteadiness of the mean load which is exhibited by some prony brakes, since this is a relatively low-frequency component. The only remedy for this type of unsatisfactory operation is a redesign of the prony brake along the lines indicated in this note.

A Suggestion for Engineering Education*

By COL. LEWIS E. MOORE

Consulting Engineer, 285 Columbus Ave., Boston, Mass.

In March 1931, I addressed the Boston Society of Civil Engineers on the subject "A Suggestion for Engineering Education." At that time I advanced certain ideas which are still, I believe, sound and which form the basis and some of the substance of my necessarily brief remarks this morning.

The results of engineering education, if judged by the place the engineer is accorded in the community in comparison with other who are less well trained and no better educated, are not satisfactory. I believe that the reason for this is that engineering education has become so specialized that the products are too often narrow technicians instead of scientifically educated gentlemen capable of taking hold of any of the branches of applied engineering science with facility and by study becoming expert in them with a good degree of success. The history of the development of engineering and engineering education may, at least in part, account for this.

It is probable that there were only two types of planners of structures in the Middle Ages, the military engineer and the architect. With the close of the Middle Ages, when war appeared to have ceased to be a major industry, the military engineer turned his attention to civil construction. In time, the civil construction overshadowed the military, and he then became known as a "civil" engineer.

At first, an engineer was assumed to be, and usually was, capable of performing all engineering duties in all lines, and to have the universal knowledge commensurate with such requirements. With the industrialization of civilization, so many new types of problems arose that one man could no longer master all lines and a degree of specialization became necessary. The first result was the formation of a group called mechanical engineers who dealt with prime movers and machinery. With the discoveries in electricity, a further subdivision called electrical engineering was constituted.

When I entered college, 48 years ago, there were only three engineering courses generally taught; namely, civil, mechanical, and electrical. Since then, many other subdivisions have been added until, at the time these ideas were originally presented in 1931, there were 73 different courses offered. I have not been able to bring this figure up to date, but will, for illustrative purposes only, assume that this figure still obtains; or would, if it were not for the impact of the war on education.

The growth of these specialties is merely a manifestation of human nature in some of its many facets. In the beginning, it was possible to teach all the fundamentals as they were then

* Presented at the meeting of the New England Section, S.P.E.E., October 7, 1944.

known and to cover as well a large proportion of the problems met in actual practice. As the students increased numerically, and the knowledge of the principles of engineering broadened, the teacher who handled several subjects became the specialist who handled only one or two.

Certain of these specialists gained considerable prominence for themselves and their schools through the publication of individual researches, originally undertaken because of their interest in the subject upon which their spare time energies were expended.

The advertising value of this was immediately comprehended by the heads of the various educational institutions, who began to insist upon their teachers pursuing research, regardless of their ability in that direction. It was carried so far that teachers were hired solely on the basis of their research qualifications, with no questions asked about their ability as teachers. It was only human to neglect teaching for research. Teachers were actually told in so many words, and I am speaking from experience, that they must either do research or write in order to be promoted.

Therefore, human nature being human nature, if a teacher could not think up some appropriate physical subject for research, he wrote a book. I was guilty on the latter count. The general result was foretold in Ecclesiastics 12:12, "of making books there is no end: and much study is a weariness to the flesh."

Human nature still being human nature, if a teacher could conduct research with effectiveness, or write well, and above all if he was a good salesman, he might be able to get a whole department or course organized around his specialty and become the head of it with all the accompanying satisfactions.

The result, the seventy-three special courses.

Let us consider the effect of this bewildering variety of educational pabula upon a young man about to enter upon his professional engineering education. He chooses, with probably insufficient information, and certainly with an insufficiently matured judgment, one of the 73 varieties offered to him. He pursues this course happily and probably with some profit educationally for four years and at the end of that period finds himself confronted with the fact that are no openings anywhere in his particular specialty. He must do something else, or else. I believe that it is unnecessary for him to bear the risk of being placed in that predicament.

Do not misunderstand me, I am not belittling research in any way; it is what has made this country great, whether conducted in a shed by Henry Ford, in the vast laboratories of the Bell Telephone Company, or in some university. However, when your money and my money is used without our consent by crack-pots for nation-wide sociological experiments, it is time to call a halt to that particular type of research.

The point that I am trying to make is that the first business of an educational institution is to educate, and that research should be a secondary objective. Teachers should be selected primarily for their ability to educate and on no other basis.

Inadequate supervision of teachers is an existing fault. I taught for ten and a half years in three of the largest universities in this country and in only one of them was there any real supervision of my performance of my duties

as a teacher. This is purely an administrative fault and arises because many heads of departments have no idea of what constitutes proper supervision; and anyhow they are afraid of embarrassing their instructors by supervising them.

An excellent way is for the head of a department to take over each instructor's classes for a week during the year. I do not recommend dictaphones in the classroom walls, although I knew of one university president who hired students to hang around the railroad station and report to him the names of the members of the instructional force who went out of town over the week-ends. This was before the days of automobiles.

I have never believed in destructive criticism. As a rule, if I cannot suggest something that seems to me to be better, I try, not always successfully, to keep still. In this case, I have something to offer and let me say that I started to try out on my own son a course similar to the one I am about to present in outline to you. It naturally could not be the same, because I had to select subjects which came nearest to fitting my ideas from the available curriculum. For the purpose I picked out Cornell University because it has not only engineering, but also philosophy and literature and arts, as well as an excellent reputation. I visited the institution myself and received wonderful coöperation from the faculty in arranging my son's courses. The outcome was that an unexpected appointment to the United States Naval Academy cut his attendance at Cornell down to only one term so that I cannot report a conclusive experiment. Discounting my natural prejudices as well as I am able to, in all my experience as a teacher, I never saw a young man develop as rapidly as he did under the type of fundamental general education that was fed to him for only a half-year. I mention this only to show that I was willing to experiment on my own. Faith without works is vain.

The table shows a four-year engineering course laid out in accordance with my ideas. It will be noticed that formal logic is included in the first term's work. This is done because it seems desirable to know something about a machine before attempting to run it; and yet the vast majority of students are put through from the kindergarten to a post-graduate course without being taught anything about brain processes or the mechanism of thought, or, in other words, without ever being taught how to think. They are expected to run the mental machine intuitively without really knowing anything about it. It would be just as sensible to ask a greenhorn to produce a complicated piece of mechanism with a turret lathe with no instruction. With much wastage of material and spoilage, he might succeed in time; but it would be much better and more economical all around to instruct him carefully in the method of operating the machine.

Years	First		Second		Third		Fourth	
Terms	1	2	1	2	1	2	1	2
Subjects:								
Logic	2							
English	4	4	3	3				
Mathematics	5	5	5					
Descriptive Geom.	2							
Physics	5	5	5	5	5	5	6	6
Chemistry		4			5	5	6	6
Psychology			2					
Practical	2	2	2	2	2	2	2	2
Materials of Eng.			3	3				
Economics				4				
Strength of Mat.				3	3	3		
Language					3	3	3	3
Bacteriology					2	2		
Professional Lectures							3	3
	20	20	20	20	20	20	20	20

I have, therefore, put logic the first thing, and have called it by its right name, because I think it is sometimes advantageous to have impressed upon one exactly what one is studying. I think logic should not be taught under the guise of English, or of any other study. Educationally speaking, I think it unwise to disguise castor oil as candy.

A course in psychology is included, again under its right name, in the first term of the second year.

Logic and psychology are included both for their intrinsic value as co-ordinators of mental processes and to offset the mental inelasticity which the rigid formalism of predominantly mathematical studies tends to create.

Descriptive geometry is included in the first term with the comment that it should be taught as a branch of mathematics, which it is, rather than as a branch of engineering drawing, as is almost universally done.

English is given considerable time because it is the writer's experience that very few engineers can express themselves in their mother tongue with exactitude and clarity.

Physics (the former name of natural philosophy is more appropriate in this particular connection) as I have used it is carried heavily throughout the whole course. It covers all that is usually given in college courses but carries each branch further. It includes applied mechanics, heat carried to the point of developing the fundamentals of thermodynamics sufficiently to give the student a really intelligent idea of its meaning, a similar treatment of electricity, and hydraulics including other fluids, as well as water.

Chemistry, both inorganic and organic, includes such subjects as combustion and should include large scale chemistry. Much may be taught by means of a test tube and a few beakers, but this does not serve to give an adequate conception of how chemical reactions are conducted on a large scale in an oil or sugar refinery.

Courses in the materials of engineering and strength of materials should include alloys and plastics as well as the ordinary materials. Probably such materials as alloys and plastics should be treated from one viewpoint in the course covering materials of engineering and from another viewpoint in the course in chemistry.

Bacteriology is included because of its importance not only in sanitation, but also in certain industrial processes.

The heading "practical" is given two hours per week throughout the course; this is intended to be used either for seminars or projects which are to illustrate some of the practical applications of the subjects which the student is studying at the time from the philosophical standpoint. If it is desired, this time could be used during the first year for shop work and drawing.

Professional lectures, to which time is given in the last year, are intended to supplement and add to the practical time by illustrating the problems of all sorts which are met with in practice and the methods of attacking them.

The total absence of such names as surveying, railroads, etc., is noticeable. It is intended that the practical hours and the course of professional lectures shall give an idea of how to attack practical problems in these and other subjects with the scientific knowledge previously gained in the study of the general subjects.

It seems to me that the time has arrived when we must admit that what is needed for the young engineer is a

broad background of training in pure science with only enough of its practical applications indicated so that the transition from the cloistered halls of learning to the busy marts of trade may be made in any available direction with a minimum of lost motion and a maximum of personal satisfaction.

Men so trained will have a scientific foundation so broad and strong that any type of engineering career can be built upon it.

The dislocation caused by the war affords a golden opportunity for institutions with vision and courage to initiate a program such as this.

Humanistic and Social Science Subjects in Relation to the Engineering Curriculum*

By F. W. ROYS

Worcester Polytechnic Institute

I have been invited to speak to you regarding the subject of Humanistic and Social Science subjects in relation to the engineering curriculum, or more especially to suggest modifications of past or present set-up in order to secure some improvement for the future.

I am perfectly well aware that this is a subject that has been under discussion for a great many years—probably it began as soon as engineering curricula came into the college program. Certainly it was under discussion and was carefully considered when the S.P.E.E. Committee, under Dr. Wickenden, made its memorable report. And now, just this spring, at Cincinnati, comes the recommendation that twenty per cent of the total undergraduate engineering curriculum should be set aside for these subjects. Thus, one fifth of the time, which is a little higher than the average noted in the Wickenden report, is recommended. This is a very substantial percentage of the total time, and, if it is that important, it is no less than criminal to allow this branch of the training to be inefficient and ineffective.

Now we profess, and are supposed, to train young men in technical fundamentals of engineering, but somehow or other we recognize, at least vaguely, that there is also great need for a broadening, general education, and we have decided that the Humanities and the Social Sciences are the subjects most likely to produce the desired effect. But we are not satisfied with what we are doing, and I think we never have been, nor do I think we ever will be unless we have a clearer idea of what we are trying to do.

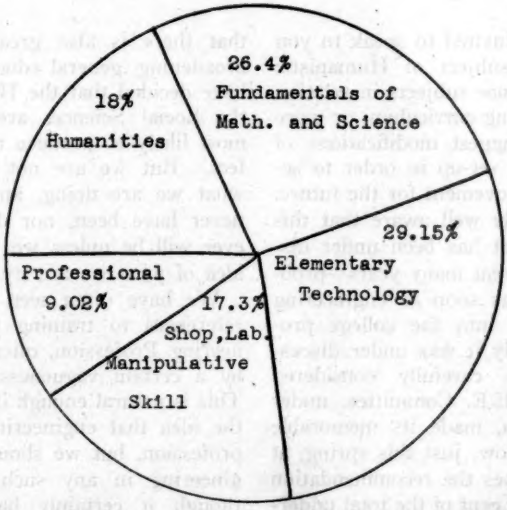
We have often seen statements or references to training for the Engineering Profession, often accompanied by a certain vagueness of definition. This is natural enough if we start with the idea that engineering is simply a profession, but we shouldn't limit engineering in any such way for, although it certainly has professional aspects, it is much more than a profession. It seems much more accurate to define it as a combination of a trade, a business and a profession—and members of the engineering fraternity are found who combine all three of these phases in all sorts of variations. It has been said that the engineer has to take the work of the scientist and make it pay dividends.

It is into this field that young men, trained by the engineering colleges, are expected to enter when they emerge upon graduation, and they have to fit in with people in all stations in life. Engineers have to know how to get

*Presented at the meeting of the New England Section, S.P.E.E., October 7, 1944.

along with all sorts of people, how to handle them and work with them in order to get results. All this requires some study and knowledge of philosophies, cultures, civilizations, economies, etc., and it is toward the development of these appreciations that we must direct our efforts of training. At Worcester we have been studying this problem at some length this summer.

Besides the 18 per cent of the Humanities, we now have about 26½ per cent given to Fundamentals of Mathematics and Science; a little more than 29 per cent to Elementary or Fundamental Technology; about 17½ per cent to Shop and Laboratory for the development of experimental ingenuity and manipulative skill, and finally about 9 per cent to Professional Applications as a sort of introduction to the work the men are to go into when they emerge from college and go into business or industry.



We in Mechanical Engineering are thinking in terms of a total curriculum of 144 credit hours for the B.S. degree. Twenty-six of these credit hours, or just over 18 per cent, are planned to be devoted to the Humanities. We think that this is enough. We think that the efficiency of the work can be stepped up so much over what it has been in the past that it will be better all around not to raid the rest of the curriculum any further in order to secure more time for the Humanities. We want to try out first the idea of making better use of the time already assigned.

We think that we have the technical part of the program on a fairly substantial basis, but we, like the rest of you, are not so sure that the big block of 18 per cent set aside for the Humanities is being used to the best advantage. We have tended like so many others to dwell on the tool value of courses in college English, language, history, economics, etc., etc., without thinking enough of the cultural value. There has been a tendency to con-

centrate on the demand for certain abilities, rather than an attempt to develop appreciation of why these abilities are important. Of course there should be an attempt to create a *desire* for such abilities instead of simply a demand for a certain standard.

All of this requires a somewhat different approach for instruction from that which has customarily been the practice. It requires a certain amount of individual deep probing into certain aspects of a subject under stimulus of a well trained and enthusiastic instructor accompanied by a more superficial study of the broader view of the subject. It is by one's own effort in probing into one part of a subject that one becomes conscious of the necessity of probing into other parts if one is to really know much about it. It is the awakening of this consciousness that is important as well as the stimulus which can be given by the instructor which prompts the student to do something about it.

One of my colleagues said the other day that when he was in college studying for his master's degree, and was being quizzed on a certain subject, the professor remarked, "You know more than is required about this subject, but you know it second-hand" and that is the trouble in these subjects of the humanities—too much of what is in the mind is second-hand. What we want is something that is first-hand, that is, something that the student really discovers about these subjects for himself, as against a lot of material that he merely remembers.

It occurs to me that we may have been rather narrow in our efforts in the past. Have we not been asking the staffs who teach these subjects to assume responsibilities for which the members of the technical staffs should be held accountable? Is it not the duty of *each* staff member to see to it that papers and reports submitted to him are in good form; that the spelling is correct and that the English is reasonably correct? Have we any right to accept from the technical staff a lack of responsibility; to allow them to say: "Oh! I can't do anything about that. That is up to the English Department"? I do not believe that it is up to the English Department. The only way to get results is to have each staff member insist on high grade presentation in this respect, as well as in technical content. Surely any competent staff member should be able to assume this responsibility. And, on the other hand, should we expect, or even wish, the staffs of the Humanistic and Social Science branches to cramp their missions, by forcing them to try to bolster up techniques for which ground work was laid in high school and which should be developed by the technical staff? Are we giving the staffs of the Humanistic and Social Science groups an opportunity to do what they should be doing, namely, expanding appreciation of the best in literature, art, music, philosophy, history, psychology, economics, political science, etc., etc.?

Perhaps you will say: Oh my! but you can't develop staffs in any college of engineering who can handle these subjects on such an elaborate scale, and the limited time is not sufficient. Of course, colleges of engineering which are parts of large universities have the staffs of the liberal arts colleges to draw upon, whereas one hundred per cent engineering colleges, especially the smaller ones, carry their own staffs for these subjects.

But it is not necessary that staff members themselves be recognized

high authorities on these subjects. They do not need to be Aristotles, Michelangelos, Homers, Platos, Miltons, Shakespeares, Adam Smiths or any other great poets, essayists, authors, artists, philosophers, economists, etc., but is it too much to expect that we can get intelligent, well-trained, enthusiastic teachers who can select the best works of these masters and who can act as interpreters and expositors of the thoughts, styles and philosophies of great men? We can perhaps expect to develop an interest in powerful exposition of worth-while ideas; of use of good English, and of knowledge and understanding of fundamental laws of economics and of human behavior. We can hope by this means and under the influence of the available staffs to expand the breadth of view; to extend the knowledge of human understanding; to improve the spirit of friendly helpfulness; to develop to some extent the appreciation of the value of humility, integrity and dependability, and it would seem as if we should plan our courses toward that end.

Perhaps we should give the staffs of these subjects more freedom to plan for the broadest, deepest development which may be possible in the time available. Perhaps we can expect students to absorb much under this stimulus and we can hope that they will improve in their powers of expression of their own ideas by some process of imitation developed from association with the best.

It may be that what I have said will not appeal to engineering faculties, but it seems clear that what we have been doing is not sufficiently effective, and perhaps these ideas will at least pave the way for further discussion.

I think it well to close with the following quotation from

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Nothing that man has contrived during his long struggle out of the jungle has so far compelled him to abandon his organized cruelty to his fellow men: *War*. Does that mean that we should fold our hands and abandon all endeavors towards further understanding, better justice, and a more enduring peace? Not at all. Science has already partly provided the explanation of man's failure to live humanely: Man's behavior machinery changes very slowly. By trial and error and through science man has changed his environments much faster than nature changes man's drives to action. But that very science gives us added courage for more persistent labor. For man's behavior does change, given time, patience, and greater scientific information.

Granting this major failure of man, despite our best in ethics, government, education, and science, we will nevertheless admit that science has already aided man towards better health, better crops, better food, better clothes, better homes, better children, better education, and better control of the forces operating in our inanimate environment. And by increasing our understanding of the nature of man and of the world, science has abolished many ancient and groundless fears. These are major achievements. So we carry on. The support of our endeavor by all our fellow citizens will accelerate our pace.

Science produces no miracles, and scientists are not supermen. The scientific method, the creed of their craft, expressed in terms of action, reads: Let us keep our mouths shut and our pens dry till we know the facts. Let us use all our intelligence and integrity with diligence to get the facts. Then, and only then, can we speak with some measure of enduring wisdom as we walk humbly among our fellow men. Let all who think that this creed might be worth trying in our social, economic, political and international relations, *lend a hand*.

A. J. CARLSON, *President*

Cooperative Engineering Education for the Teacher — Industry's Opportunity

By W. J. SEELEY

Chairman, Dept. of Electrical Engineering, Duke University

The philosophy underlying cooperative engineering education and its many advantages are well known to most engineering teachers. It would be well, however, if this type of education could be extended to cover the teacher as well as the student, thus giving the teacher all the advantages accruing to the student plus the real engineering experience which he so greatly needs. What the student learns in industry he keeps, what the teacher learns is largely passed on to others. It would seem, therefore, that some well planned industrial experience for the teacher eventually would pay handsome dividends to industry at large in the form of better engineers.

Many engineering teachers have gone into temporary war work in industry and the many military laboratories. Some of these former teachers had trouble getting on with others and seemingly were not too well liked by fellow workers. Criticisms such as the following have been leveled on them by fellow workers and subordinates: purists, individualists, too academic, prima donnas, not practical, unwilling to abide by the rules of the organization and proceed through proper channels, no appreciation of the steps involved between conception and production, more interested in advancing themselves and their projects than the overall product of the industry, etc.

Many of these criticisms are justified because the teacher, by the nature of his work as a teacher, becomes a peculiar individual. He very often is the sole boss of a course, having complete charge of selecting text, making assignments, setting examinations, and awarding grades. His mental contests are always with immature and undeveloped mentalities tending to glorify him into a sort of intellectual god. At the same time he is looked up to with respect and awe, sometimes with fear; he is considered to be an authority by his students because he knows all the answers. In short, he is classified as a big shot. It is not any wonder then that eventually he believes actually that he is an outstanding authority and a gentleman of importance—probably way beyond anything deserved. The situation is exactly similar to the saying that "if you call a man a crook often enough he will soon become a crook." If a teacher has undesirable characteristics it is because of the limited environment in which he grows. He needs some tempering experiences, those provided by industrial and engineering activities.

The teacher who has had experience with a public utility, industry, or laboratory has it all over the inexperienced teacher. In the first place, he has had some practice at real engineering, and after all is said and done a teacher of

engineering certainly should be an engineer. His experience gives him an acquaintance with the type of problems faced by the young engineer; he sees what industry expects of the engineer; he learns to work in cooperation with others; he is in competition with men of equal ability; he sees the problems of both labor and management; he learns that his work is not an end in itself but a contribution towards the whole; finally, that great humanizing factor—he becomes a little modest and learns that he is not a big shot.

The most valuable experience a teacher can have is that of working with other engineers. There is nothing the writer would exchange for the experiences gained in walking the right-of-way of a transmission line, or crawling around through a water wheel, or testing bushings, or transformer oil! The three summer months spent in such activity will be worth considerably more than the same time spent in additional teaching, and again, the teacher of engineering should also be an engineer. Promising young men too often are taken directly from college and thrust into teaching with no industrial experience whatsoever. The teacher's first interest and first love certainly should be teaching. The institution will see that he gets proper teaching experience. Here is industry's opportunity to see that he gets proper engineering experience.

In normal times the teacher is hired and paid for nine months' work. The three additional months are available for vacation (if he has learned to live on a low income), or for working towards an annual income. The latter is nearly always a necessity if he is to stay in teaching and at the same time become a normal citizen and raise a family. He is highly tempted to take a summer school teaching job because he can live at home and earn a three months' salary commensurate with his nine months' income, thus giving him an adequate annual income. The more desirable summer activity, however, is to go into industry, but—and here is the crux of the whole situation—he cannot earn as much there as he can at teaching, because as a temporary employee he simply is not worth it, and he probably has to live away from home. For example, a public utility would hesitate to pay $300 per month to a summer employee who is serving as a helper on a line crew, say, in order that he should have this (or similar) experience. Or what industry would pay $500 per month to a professor serving temporarily in the personnel office in order to obtain experience in methods of evaluating and promoting engineers? In other words, industry would have to pay the teacher more than he is immediately worth. If industry could be persuaded to do this an enormous contribution would be made to engineering education, and it certainly would pay dividends to industry in the long run.

This all boils down to industry's willingness to provide remunerative summer jobs for teachers. These should be real jobs (not courses of lectures) in which the employee carries his lunch and punches the clock. The young teacher should select his industry, or industry select the teacher, and they should stay together for five or six summers, thus allowing for change of department and advancement in position. Cooperation carried out along a definite plan to progress as the young man progresses in his teaching thus will result in better teachers, better students, better engineers for industry. This is a real opportunity for industry to do something concrete for engineering education.

How Do YOU Do?

By ARTHUR M. HILL

Professor of Heat Engineering, Tulane University

Much has been written concerning student appraisal by the faculty—reversing the process might be interesting and instructive. Too often, teachers, covering the same subject year after year, become oblivious to various undesirable personal traits that may be developing.

Sometimes caricatures enacted at faculty-student banquets are very enlightening, and bring home forcibly to the jittery faculty member his annoying habit of pulling his nose while lecturing, or forever adjusting his glasses, etc.

An effective teacher keeps before him at all times the thought that he has a bill of goods to sell, not just a presentation of facts, but an *interesting* presentation of facts.

At a first class meeting recently, the students were asked to list on the board, for discussion, qualifications of a good teacher. Here are the qualifications which *they* thought were important:

Knowledge of subject
Patience
Ability to explain clearly
Reasonable time for absorption
Enthusiasm
Punctuality
Proper preparation
Enunciation
Sympathy with the class
Impartiality
Prompt return of quizzes and homework
Ability to give representative quizzes
Recognition of student's background
Willingness to answer questions
Encouragement of students
Penmanship.

This list is a sincere analysis of what the students, in this case engineering juniors, as a group felt were desirable qualities in a teacher.

How many of us can apply this list to ourselves and truthfully say that we fulfill most of these characteristics?

Engineers as a group are frequently criticized for lack of ability to present effectively subject matter at public or professional meetings, yet how many men who spend their lives training young engineers give consideration to impressive presentation of their own lecture material? Certainly examples of brilliant performance by the teaching staff must, in a measure, influence the habits and training of the students.

After discussion by the students of various desirable faculty characteristics, they next listed what they considered good student qualities. These were:

Preparation
Interest in the course

Neatness in (a) work, (b) dress
Punctuality
Proper foundation
Participation in class discussion
Mature conduct
Perseverance and patience
Penmanship.

The role of the teacher is not completely fulfilled unless he gives some consideration as to what his audience thinks about his presentation. Taking stock of one's self, and then doing something about it, requires courage, will power and determination.

Post-War Undergraduate Training of Engineers*

By OSCAR S. BRAY

There has been much speculation about the approaching post-war period. Whatever else may happen, it is safe to say that there will be no fundamental change in the responsibilities of the engineering educator. The public will still expect him to turn out graduates who will become outstanding citizens, leaders in their communities.

Employers of engineers will continue to look to the colleges for mentally alert young men, well grounded in engineering fundamentals and with enough guts and gumption to stick with a tough job and whip it. I do not doubt that students will continue to graduate believing themselves fully equipped for a successful career, personal as well as professional.

Some aspects of the general post-war picture are already becoming apparent. There is in prospect an enormous amount of work to be done to put the world in order, both at home and abroad, much of which will devolve on the engineer. Indeed it is not unlikely that we shall see as the post-war period develops a definite shortage of competent engineers. An accelerated foreign demand for American professional men, particularly from China and Russia, may also be in prospect.

The practicing engineer will find his projects becoming increasingly complex and his studies and design methods more detailed and more refined. The broad social and economic effects of engineering works will require more and more study. Specialization will become increasingly necessary as requiring knowledge in the engineer's field increases in depth.

It appears probable that the union movement will continue to trouble the engineer for years to come and that the sub-professional group will in time become nearly completely unionized. I doubt that unionism, or even collective bargaining as it is now operated, will make permanent gains in the fully professional group.

Turning now to the colleges themselves, there is no reason to suppose that the pre-war increases in college enrollment are at an end, nor would it be surprising if enrollment in the professional schools increased at an even greater rate than the average. It appears probable that many of the women who have made places for themselves in engineering offices will remain there after the war. Their success will be reflected in the number of women seeking a technical education.

In short, the future picture indicates that we must have from the colleges better engineers in the future than we have had in the past. And training is only part of the story. Personal observation over a period of years convinces me that we have turned out too

*Presented at the meeting of the New England Section, S.P.E.E., October 7, 1944.

many sub-grade men from our engineering schools. We have wasted much valuable time and clogged our facilities with individuals who were not suited to the educational level to which we were attempting to raise them. We have, in short, tended toward the production of technicians rather than engineers.

I think that when this war is over and we start paying off our wartime debts, we shall no longer be able to afford the luxury of a degree for all who are financially able to remain in college long enough to acquire it. And by the same token, we cannot afford not to educate fully those students who are worthy, regardless of their financial condition.

Top grade concrete cannot be made from second grade materials, nor can top grade engineers be made from second grade students. The obvious answer in both cases is, of course, selection of materials. It is unfortunate, but not negatively compelling, that selection of students is not as simple as selection of concrete materials. The problem involves not only difficulties of method but also what may be termed public relations or even political troubles. This is particularly true of those institutions drawing a large part of their support from public funds. Yet I believe it can be done, and I believe that our concern in doing it should be not that standards are too high, but that they may be too low.

Engineers have very aptly been termed the Sons of Martha. On them, perhaps, more than on any other group falls responsibility for mankind's material welfare. To discharge that responsibility adequately in the days to come will require the best men and minds that we have. Our engineering schools should insist on that best.

Selection of students in the past has been based very largely on scholastic attainments. That such a basis for selection is not the whole answer has been demonstrated frequently by the successful careers of men who graduated well below the magic "upper quarter of the class." Such qualities as imagination, moral courage, leadership, native intelligence and capacity for work are of equal or greater importance than mere ability to learn (which may indicate only a retentive memory) and should be given full weight in any decision to accept or reject an applicant.

Students once accepted should not be forgotten until graduation, but their continuance as students should be conditioned upon their continuing expanding development. A young man's value to his employer is often measured as much by his capacity for growth as by his present stature, a factor which should be considered.

The pre-war trend toward lower age of entrance in our technical schools is regrettable. I do not believe the average boy of 17 is mature enough mentally to derive the greatest benefit from college classwork or, also important, from the social side of college life. This situation may correct itself if, as now appears probable, some form of universal military service for young men is adopted in this country.

The curricula now in general use appear to be adequate, though the deadwood needs trimming. Surveying, for example, consumes a disproportionate amount of the student's time and might well be eliminated. Any intelligent engineering graduate could study Professor Breed's excellent text on the subject and be able within a week to handle any routine

surveying assignment, those involving instrumental skill excepted.

Railway engineering, likewise, is useful to only a small number of graduates, and draughting is a subject that should be taught in the high and trade schools. Individual colleges may be teaching other subjects of limited utility. The curriculum should be scanned and such courses pruned with a firm hand.

Much has been said in recent years about the dangers of specialization. Its critics contend, and with some truth, that the student cannot know two, three or more years in advance what field he will finally adopt. As I have indicated earlier, I believe that specialization will become more and more necessary in engineering as it has in medicine. I believe also that specialization should be done in the colleges by intent rather than in practice, as is often the case, by accident. Specialized knowledge gained during the student's undergraduate career comes (if he has chosen his school wisely) from outstanding men in the field. It is generally broader, and in many cases sounder than when acquired in practice in a single office, under the influence of a man of fixed and definite opinions.

I do not believe the present 4-year course is long enough to include the thorough grounding in fundamentals necessary for an engineering career, to permit the teaching of worthwhile but essential amounts of such non-technical subjects as accounting, business administration, finance, ethics, history, political philosophy, literature and language, and at the same time permit successful specialization. The undergraduate course could well be lengthened to five years, the first three devoted to fundamentals and non-technical material, and the remainder to the student's chosen special field. I may say, in passing, that the non-technical subjects should not be treated as stepchildren, but should be taught as full members of the family.

Whatever is done about specialization, the major emphasis should be on fundamentals—mathematics and its application to the solution of engineering problems, physics, chemistry, mechanics, statics, dynamics, theory of structures, strength properties of materials, geology, economics, oral and written English. English might well be placed at the head of the list of fundamentals for without the means of conveying his ideas clearly and completely, no technical man can be fully effective.

The teaching of accounting, business administration and finance has been mentioned. These are essential in any engineer's training, necessary in his professional career and equally useful in the guidance of his personal affairs. The relationships between professional success, material prosperity and public recognition being what they are, the matter of equipping the engineering student with proper tools for solution of his personal management problems should not be overlooked.

Having talked of students and courses, we come finally to perhaps the most important factor in the production of engineering graduates, the faculty. The personal and professional influence exerted by his teachers on the young engineer during his formative years is difficult to underestimate. For this reason, and just as students should be selected for ability, so also should faculty members be chosen for their outstanding qualifications. This selection should extend from the dean to the youngest instructor. Whether the colleges can continue to secure

young men of the desired high quality at prevailing salaries is an open question.

With certain exceptions, I believe the actual teaching of engineering should be confined to those who have had first hand experience in application of its principles. Briefly, engineering should be taught by engineers—successful practitioners of the art. I believe particularly that development of teachers through the graduate student teaching fellow instructor route handicaps both the teacher and his pupils and should be avoided. The more logical approach would seem the graduate student practicing engineer-instructor path, recognizing, of course, the difficulty of luring the successful young engineer from practicing his profession to teaching.

The teaching engineer should not lose touch with his field, but should continually refresh his "feel of the dirt" by maintaining close contact with practicing engineers, visiting their offices and their projects to see for himself what is going on. A return to practice at 5-year intervals would be most helpful, particularly to the junior members of the faculty.

I should like to see also the institution of frequent guest lectures by prominent local members of the profession, most of whom would consider such an opportunity an honor and a privilege.

I am under no illusions concerning the problems faced by the colleges, nor am I unaware of the difficulties inherent in the suggestions I have made. That you have arranged a meeting such as this is the best proof that could be offered of your determination to improve your methods and your product, and I am confident that you will find the solutions where the results to be achieved are sufficiently great.

Reconversion of Educational Research*

By L. E. BECK

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In preparing to reconvert our programs of engineering education to the purposes of peace, we find that the restoration of educational research to its proper place is one of the problems of major importance. The dislocations in this phase of our work have been especially severe. Wherever possible these programs have been devoted to developing immediately usable instruments of warfare and means of wartime production. We may note in passing that in this regard they have given an excellent account of themselves. Where the programs could not be directed into war work, they have been drastically curtailed. This has been necessary because of the scarcity of physical facilities and the stringency of manpower.

Under such circumstances we may well profit from a re-examination of our research programs in terms of their functions in the educational system and regarding the policies and procedures which contribute to performance of these functions. Lacking this, we are very likely to strive for simple reinstatement of our pre-war systems, for which few of us would claim perfection.

First of all we seek to acquire a perspective whereby we can see the research programs in their proper relation to the curricular and other programs of the institution. Here it is important to recognize that a research program is merely one phase of the over-all educational enterprise, and that for proper effectiveness it should be neither under-emphasized nor over-emphasized. In some institutions the research programs have been very meager, with the staffs devoting almost all of their time to course work. In certain others it seems that the staff members devote their best efforts to research, with teaching effectiveness being taken more or less as a matter of course. Evidently the most desirable condition exists in the middle ground wherein a proper balance is maintained between course work and research, with the two functions being coordinated and supplementary.

This balance rests in large measure upon the policies followed by the administrative officers of the institution. Where administrators base their promotions and salary increases largely upon publications and research successes, research becomes predominant. Where teaching services are the sole criterion, research is neglected. The best situation exists where advancement is made on the basis of both teaching performance and research

*Adapted from the report of the Committee on Research of the School of Electrical Engineering, Purdue University. Committee members: J. R. Eaton, G. V. Mueller, F. O. Nottingham, R. P. Siskind, C. S. Sprague, and L. E. Beck.

success, with due recognition being given to the fact that the good teacher is not necessarily a good research worker and vice versa.

The objectives of the research program in an engineering school may be stated as follows:

1. Improving the educational work of the school by:
   a. Training students in research procedures
   b. Enriching the experience of teachers
   c. Maintaining an environment of research activity and progress
2. Extending the bounds of technical knowledge through:
   a. Fundamental research
   b. Applied research
3. Providing service to the public through:
   a. Publications
   b. Technical services in those fields in which the school has especially good facilities.

With a satisfactory program for attaining these objectives, the incidental aim of advancement of prestige of the school and progress of the individual may be attained as a matter of course.

The research work of an engineering school may be conveniently considered in two general catagories: that which is supported either directly or indirectly by external sponsors; and that which is sponsored entirely by the school. Projects in the first category are usually undertaken for specific purposes and the disposal of results of such research is ordinarily determined according to a pre-arranged plan. Projects in the second category are usually more informal: they may be conducted for any one of a wide variety of purposes and the results of such research may be used almost entirely at the discretion of the school.

Probably the most significant change in our research programs has been the shift from the informal to the formal type of project. Prior to the war, a considerable proportion of the students who were awarded degrees in engineering received some training in the informal type of research project through the medium of a student thesis. At the present time, much of the thesis work has been eliminated. Probably this shift is largely due to the fact that student research calls for relatively large expenditures of staff time and physical facilities, both of which are difficult to provide.

An evaluation of the current research programs in terms of the stated objectives shows that our attainment of these objectives is quite meager. The instructional aspects are curtailed because the secret nature of the projects does not permit wide participation of students and teaching staff in the research program. Fundamental research has necessarily given way to applied research, and the publication of results is deferred because of the confidential nature of the projects.

During the war emergency these conditions are necessary. But it would be unfortunate to carry them forward unaltered into our peace-time program. We believe that, when the opportunities to do so present themselves, efforts should be made to increase participation by members of the teaching staffs in the research programs, to expand the research training of our students, especially those undergraduate students who intend to seek employment in the more technical phases of engineering, and to encourage the preparation of technical papers based on research work.

The primary need in a program of engineering school research seems to be the provision of adequate physical facilities. A large proportion of the projects undertaken are experimental in nature, and not simply analytical. Merely providing a space in which to work on such projects is not sufficient. Too often the investigator finds that most of his time is taken up in procuring materials, in arranging for the use of equipment, and in constructing makeshift devices for use in carrying out the investigation. Too often he must obtain his materials from stock carried primarily for maintenance of laboratory equipment, and must depend upon the chance availability of maintenance shop equipment for doing his machine shop work. Sometimes the mere details of arranging for the use of such facilities consume more time than the actual investigational work.

If educational research is to be carried on efficiently, the system of shops and stores must be so arranged as to make these facilities readily available to the investigator. Such a system should include not only space in which to work and tools with which to work, but also sympathetic supervision and assistance on the part of a skilled experimental machinist. It should recognize that the students are not skilled craftsmen, and that the training which they receive in working with materials and tools is a worthwhile phase of their education. It should recognize also that occasional damage to equipment is unavoidable in such a program, and that the incidental maintenance represents a legitimate part of the expenditure for such training.

Shop space and equipment should be provided to meet this need. One section of the shop might be equipped for hand work and the simpler machine operations requiring only superficial supervision, and another section might be equipped with the more intricate machines which would be available to research workers only under strict supervision of the attendant.

A stock of the more commonly used supplies should be built up and made available to research workers under the proper supervision. In electrical engineering, for example, this stock should include such items as screws, bolts, sheets, bars, wire, and a few of the more commonly used circuit elements like resistors, capacitors, and inductors. Probably it will become possible to obtain a considerable supply of some of these items at low cost by salvaging parts from obsolete equipment which becomes available at the end of the war.

A second important need is the allowance of adequate staff time for supervision of this work. The proper supervision of research work calls for a very large expenditure of staff time, and it cannot be expected that a research program will be successful if these duties are merely superimposed on a full schedule of teaching. The value of student research, especially at the bachelor's and master's level, lies predominantly in the training of the student, and the supervision time is therefore a legitimate charge against the instructional budget of the school. In a few cases the added benefit of publication may be attained and in rare cases discoveries may be expected which will justify patenting procedures.

The difficulties of making an equitable time allowance for research supervision tend to lead to the practice of making no allowance for it at all, with the consequent deterioration and disappearance of the work. Successful projects must be very carefully devised and evaluated before they are

undertaken. Once the propect is under way, the very fact that the student is in need of training calls for close and sympathetic supervision. And finally, the supervisor must expect to provide considerable guidance in the presentation of results.

In the final analysis, probably the supervisor himself is the only person who can make a very good estimate of the time required. But to put the matter on a reasonably definite basis, it is suggested that the supervision of a student research project be considered the equivalent of at least one contact hour per week of teaching.

It is recognized that this is a relatively expensive form of instruction. Nevertheless it is worth the cost for those who have the proper qualifications. It should not be wasted on students arbitrarily asigned to such work against their will. Ordinarily it should be handled on an elective basis, with adequate allowance of credit toward the degree. It might be desirable to establish a minimum scholarship index requirement for eligibility to such training.

In some projects the cost of the investigation is borne by sponsoring agencies, and the use of results is definitely limited by contract. Their primary objective is the discovery of technical facts. In other projects the research is informally sponsored by the school as a part of the preparation for a degree. Their objective is primarily instructional. In a middle ground there may be projects which are supported to a greater or lesser extent by external grants and in which the use of results may be more or less free. The interests of the school are best served by maintaining a proper balance among these types.

Projects sponsored by industry are valuable to the school, not only because they are self supporting but also because of the contacts with industry which they provide. It is to be expected that in a field of applied science like electrical engineering such projects would tend to involve applied research rather than fundamental research, with a corresponding tendency to restrict the use of results. It is to be hoped, however, that when the war ends it will become possible to handle such projects on a less confidential basis so that the work can be distributed more freely among members of the staff and student body and so that more publications will result from it. It is recognized that it is necessary to keep certain types of research confidential. While it is probably preferable to have such confidential work done by the industrial concerns in their own laboratories when facilities are available, the engineering school can render an important service by handling such projects for sponsors who do not have adequate facilities of their own.

Probably the greatest need is the extension of the instructional type of projects which are carried on by students and are supervised by the instructional staff. Such projects should be evaluated primarily on the basis of the training they provide for the student rather than in terms of their contributions to technology. This work will probably be done mainly at the level of the master's degree, since the present trend seems to be to encourage the more technically inclined students to acquire their more specialized training in a post-graduate program. However, an effort should be made to interest this select group in investigational work prior to their graduation and this might well be done by means of undergraduate research work of the

appropriate degree of difficulty and with the proper allowance of academic credit.

While the primary aims of educational research are the improvement of instruction and service to the public, the possibilities of personal advancement through publications and patents may be powerful incentives to the individual workers. To be most effective any incentive must be fairly definite and its possibilities must be known in advance. A more definite statement of policy on this matter would be helpful as a stimulus to research work in most cases, and the policy should be made clear to all staff members.

It must be recognized that the establishment of such a policy is not a simple matter. Especially in tax-supported institutions care must be taken to safeguard all of the equities involved. On the one hand, it is clear that the expenditure of tax money for the personal gain of the employee cannot be justified. On the other hand, the institution should not make a profit from the creative efforts of its employees unless such creative efforts are a definite part of the consideration in the employment.

In those projects sponsored by industrial organizations and research foundations the rights of publication and patenting are usually covered by contract. If the individual worker on such a project is adequately informed regarding his status, no difficulties should arise.

In those projects which are not formally sponsored the proprietary relations seem to be in need of clarification. Almost all of such investigations are sponsored by the school primarily for educational purposes, and the extension of technological knowledge may be considered to be incidental. While such projects may lead to discoveries of importance, the possibility that a given project would involve invention on which a sound patent situation could be built is quite small. The chances of developing a suitable topic for publication are very much better.

As a step toward clarification of the status of those who are conducting or supervising research projects not handled through formal contract the following general policy is suggested:

1. That the school support only such projects as represent definite educational values, either in the training of students or in the enrichment of experience of staff members.
2. That the expenditures made by the school in support of such projects be considered as payment for educational values created in behalf of the students and the public.
3. That staff members who devote part of their employment time to such work have the obligation to promote educational purposes thereby through the training of students and publication of such results as merit publication and are not confidential in nature.

The status of staff members who make patentable discoveries or inventions not connected with projects covered by contract is often quite indefinite. The practices in the various institutions range all the way from direct assignment of such rights to the institution or its designated agency on the one hand to complete freedom of choice by the individual on the other. The issue involved is a controversial one which is beyond the scope of this article. But regardless of the policy

being followed in any given institution, it seems clear that a complete understanding of that policy on the part of the staff will result in better work and fewer misunderstandings. In addition, it appears that any investigations which do not contribute to the educational venture in some way should not be undertaken.

In conclusion, we may say that in considering educational research, the emphasis should be on the word *educational* rather than on the word *research*. While many far-reaching advances in technology have emanated from educational laboratories in the past and may be expected from the same source in the future, the main burden of such work is now carried by industrial laboratories and research organizations. The primary aim of educational research programs is the training of personnel for service in technical pursuits.

A Century of American Textbooks in Mechanics and Resistance of Materials

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It is said that "all the important formulae of modern mechanics were discovered and employed in the period of Galileo and Newton" (1). However, this statement applies only to the philosophic and not the engineering view of mechanics. Furthermore, the terms applied to the different quantities have changed, the importance attached to various topics has shifted, concepts have gradually enlarged, and new ways of presenting the subject matter have been devised and used. Resistance of materials, unlike theoretical mechanics, is new for it has been developed *since* the time of Galileo and Newton and most of it within the past one hundred and twenty-five years.

My purpose is to trace some of the changes which have taken place in these subjects over the period from about 1800 to 1900. The two topics of mechanics and resistance of materials will be discussed separately.

Engineering Education

European and American

Before engineering textbooks can be interpreted and evaluated properly, it is necessary that we have a clear understanding of the beginnings of engineering education and of the philosophies which have at different times nurtured it.

What we may call the beginnings of formal engineering education began in France with the school which was connected with the Corps des Ponts et Chaussées, which Corps was begun in 1716. From that time engineering schools were established about as follows:

Corps des Ponts et Chaussées	1716
L'École des Ponts et Chaussées begun by Perronett	1747
L'École des Ponts et Chaussées given official recognition	1775
Bergakademie, Freiberg	1765
L'École Polytechnique	1794
First graduate of United States Military Academy	1802
United States Military Academy reorganized by Col. Thayer	1817
Rensselaer Polytechnic Institute begun	1824
Rensselaer Polytechnic Institute offered course in civil engineering	1829
Rensselaer Polytechnic Institute graduated first civil engineering student in English-speaking world	1835
Rensselaer Polytechnic Institute remodelled after French schools	1849
First formal teaching of civil engineering in England begun in University College, London	1840
Chair of civil engineering founded at University of Glasgow by Queen Victoria with W. J. M. Rankine as Professor	1840

School of Engineering at Union College	1845
Lawrence Scientific School, Harvard	1846
Sheffield Scientific School, Yale	1847
First engineering college in India	1847
Chandler Scientific School, Dartmouth	1851
Engineering Department organized, University of Michigan	1852
University of Michigan offered course in engineering	1853
University of Michigan awarded degrees in engineering	1860
Columbia School of Mines established	1864
Massachusetts Institute of Technology begun	1865
Thayer School of Civil Engineering, Dartmouth	1867
Worcester Polytechnic Institute	1868
University of Illinois (one of the Land Grant Colleges)	1868

The influences which bear upon an institution are potent factors in determining the trend of its educational thought and processes. These factors affect not only the content of the courses but also the mode of presentation of the subject. In the early days the best example of advanced scientific engineering education was in France where the highest type of mathematical analysis as applied to engineering was taught to students who were adequately prepared to assimilate this type of training. These men were not taught shop work, manual training and similar courses and, as a consequence, the engineers educated in the French school were highly theoretical. During the same period the English engineers were educated through a system of apprenticeship which envisioned a degree of self-education added to the practical background. The philosophies which guided engineering education in the two countries were direct opposite. French conditions brought forth so highly theoretical French books b the English conditions did not bri out books in England of high theoret cal quality.

Previous to about 1800 there was engineering education of any sort, e cept the most rudimentary kind, America.

Analytical Mechanics

Early Literature

Formal engineering education beg in America before it began in Engla and it was natural that at first Amer can technical education should follo somewhat the French type. This ten ency is borne out by an investigati made in 1933 by Ralph Shaw of t Engineering Societies Library (7 He found that of the books and pe lications of interest to the engineer his professional capacity (exclud mathematics, mechanics, etc.) up 1830 there were 692 titles of which per cent were published in Engla 32 per cent in America and 27 per c in France and only about 4 per c in all other languages. Between 18 and 1860, Shaw states, the Ger publications increased at the expe of the French publications.

Previous to about 1850 mechan was taught in and as a part of Natu Philosophy (physics) and some of t liberal arts colleges, such as Harva Dartmouth, Yale and others, offer courses in mechanics in the depa ment of mathematics. In most c the work was highly theoretical a not intended for or adapted to e neering purposes. Even so this tea ing exerted an important effect on t scientific thinking of educated men that time.

The principal source books of mechanics may be said to be:

Archimedes whose method of approach was simply the lever.

Stevin, 1586, De Beghinseln der Weeghconst (Principles of Equilibrium).

Galileo, 1638, Discourses on Two New Sciences.

Huygens, 1673, Horologium Oscillatorium.

Newton, 1687, Philosophiae Naturalis Principia Mathematica.

Keill, 1700, An Introduction to Natural Philosophy (English translation 1720).

Varignon, 1725, Nouvelle Mécanique ou Statique.

Gravesande, 1731, Trans. by J. T. Desaguliers, 4th Ed., Mathematical Elements of Natural Philosophy.

Euler, 1736, Mechanica sive Motus Scientia Analytice.

D'Alembert, 1743, Traité de Dynamique.

Musschenbroek, 1744, The Elements of Natural Philosophy (English translation).

Emerson, 1758, 2nd Ed., The Principles of Mechanics.

LaPlace, 1799, Mécanique Céleste.

Poisson, 1833, 2nd Ed., Traité de Mécanique.

Lagrange, 1853, Mécanique Analytique.

Most of the books in this list were not particularly suitable as textbooks in the modern sense but they furnished references for the teachers and for advanced students. How many of them were available in the various universities and colleges in the early days is uncertain but most of them were probably available in some university or private library.

Among the textbooks written previous to about 1900 on what may be called engineering mechanics the following are important:

Foreign

Atkinson, T., 1785, A System of Mechanics.

Gregory, O., 1805, A Treatise on Mechanics.

Bridge, B., 1814, A Treatise on Mechanics.

Boucharlat, M., An Elementary Treatise on Mechanics. Translated from the French in 1833 by E. H. Courtenay.

Whewell, W., 5th Ed., 1836, An Elementary Treatise on Mechanics.

Rankine, W. J. M., 1858, A Manual of Applied Mechanics.

American

Olmsted, D., 1831–1891 (many revisions) An Introduction to Natural Philosophy.

Bartlett, W. H. C., 1853, Elements of Analytical Mechanics.

Peck, W. G., 1870, Elementary Treatise on Mechanics (No calculus).

1887, Elementary Treatise on Analytical Mechanics (Calculus).

Wood, DeVolson, 1876, The Elements of Analytical Mechanics.

1877, The Principles of Elementary Mechanics.

Bowser, E. A., 1884, An Elementary Treatise on Analytical Mechanics.

Lanza, G., 1885, Applied Mechanics.

Church, I. P., 1887, Mechanics of Engineering.

Michie, P., 1887, Elements of Analytical Mechanics.

Wright, T., 1896, Elements of Mechanics.

Maurer, E. R., 1903, Technical Mechanics.

Obviously no attempt has been made to make the list complete, especially in the later years, but only those books are mentioned which have had rather large sales and which may be presumed to have exerted a correspondingly large influence on engineering or technical education.

A study of the mechanics books named in the preceding lists will indicate the truth of the opening sentence of this paper, namely that all the important formulas were long since known. Nearly all of the books deal

with concurrent, coplanar, and non-coplanar forces, center of gravity, mechanical powers of pulleys and machines, impact, rectilinear and curvilinear motion, pendulums. Yet the method of approach, the placing of emphasis varies greatly over the period mentioned. Such tools as the free-body diagram and the joint and section methods of truss analysis did not appear in American textbooks on mechanics until about 1880.

One of the most pronounced variations in the various textbooks is in the mathematical presentation, of which there are three types. The term Euclidean, called synthetic by some writers, may be used to describe the method of approach in which the proofs are geometrical and the reasoning is by ratios and proportions, following somewhat the methods used in the fifth book of Euclid. In this mode of presentation axioms are assumed, lemmas and propositions are demonstrated, corollaries are established and scholia are deduced, following somewhat the method employed by Newton. (It is an interesting fact that though Newton created the calculus he did not use it in writing the Principia.) At the other extreme is the algebraic method which forecasts our present or analytical type of analysis. Finally there is an intermediate method which preserves the terms and form of propositions, corollaries and scholia and which makes some use of ratios and proportions but which is essentially algebraic.

In order to compare different authors it should be remembered that besides the different modes of presentation there were two schools of thought developed along different lines, the Newtonian method dealing with force, mass and acceleration, and the French, or more properly the continental, method following Huygens, D'Alembert and Lagrange and using the newly developed analytical method and the ideas of work, energy, and virtual velocities. The contrast between the two schools of thought is great.

Mechanics at the United States Military Academy

In America the foundations of engineering or technical education were first taught at the United States Military Academy at West Point. The really effective beginning of this institution was in 1817 when Col. Thayer, "the father of West Point," returned from his studies in Europe and took charge of the Academy where he continued until 1833. As a consequence of the thorough mathematical training given at the Military Academy, it occupied a position of commanding importance in early engineering education in America. Up to about 1850 Rensselaer Polytechnic Institute and Union College were the only distinctly civilian engineering schools in America and since most of their teachers had been educated at West Point the teaching at the Military Academy set the standard as well as the pattern. Between 1833 and 1876 the only important American textbooks in analytical mechanics were those written by West Point teachers and graduates. Consequently, a discussion of the mechanics taught and the textbooks used at West Point will represent the general character of engineering mechanics before 1850.

It is reported that at the Military Academy from 1802 until 1812, "Occasionally some of the more advanced students were taught mechanics and practical astronomy from 'Enfield's Institutes of Natural Philosophy' " (3). In 1812 a department of Natural and

Experimental Philosophy was organized and it would appear that Enfield's Institutes continued to be used.

Gregory's "Treatise on Mechanics" was first used in 1818 but it was found very difficult by the students and in 1819 it was decreed that only the first section (highest) should use it. The second section should study "a corresponding, but more easy and familiar, course of mechanics. . . . They have reason to believe . . . that Parkinson's 'Mechanics' . . . will be found suitable" (4). In 1820 the Academic Board definitely adopted Gregory but in 1824 Bridge's "Treatise on Mechanics" was adopted for the lower sections (5). How long these two textbooks were used is uncertain but in 1830 Francoeur's "Traité Elémentaire de Mécanique" was in use by the first section and Boucharlat's "Traité de Mécanique" by the second section. The French edition of Boucharlat's book was adopted in 1831 and Courtenay's English translation of it in 1833 (6). Courtenay's translation of Boucharlat was used until 1850 when it was superseded by Bartlett's "Synthetical Mechanics" which in 1853 was replaced by his "Analytical Mechanics" (7). There was then no change for thirty-three years when, in 1886, Michie's book, "Elements of Analytical Mechanics," was adopted and used until about 1902.

Exposition in Foreign Books

Practically all of the mechanics textbooks of 1890 or earlier included a treatment of the mechanics of fluids but this topic will not be considered in this paper. The first edition of Gregory was published in 1805 with a third edition, which consisted of two volumes of text and one volume of plates, in 1815. The fact that it was translated into German in 1828 suggests that it was held in some esteem. There are 162 pages devoted to statics and 183 pages to dynamics. The book was written, according to the preface, in an effort to bring together the efforts of the mathematicians and the practical engineers of that time. Gregory says in his preface, "a forbidding distance and an awkward jealousy seem to exist between the theorists and the practical men engaged in the cultivation of mechanics in this country," and he goes on to point out that it is a common feeling in England that "a man may become celebrated . . . in the construction of machinery, while he is completely unacquainted with the principles of mathematics."

Gregory uses the Euclidean method. He first states a proposition to be demonstrated, then proceeds through the various steps and finally arrives at a satisfactory result marked Q.E.D. On the basis of this demonstration he then deduces corollaries and scholia. Gregory at times resorts to calculus or fluxious instead of Newton's geometrical mathematics, but in the calculus he adopts the notation of Newton rather than that of Leibnitz. Sometimes he employs trigonometry and the method of proportions, of which the following is an example: "When two bodies have different uniform motions, the spaces described are proportional to the times and velocities jointly, or $s:s'::v:v'$." The preface contains a long argument to justfy his utilization of fluxions because he feels that some people will think his mathematics are not elegant enough. He uses the "parallelogram of forces" and the ideas of and the equations $\Sigma F_x = 0$, $\Sigma F_y = 0$, though he does not use this notation. He works no numerical problems and does not avail himself of the method

of work and energy. Many references are given to other books, both theoretical and practical.

Gregory was taught, as previously indicated, at the United States Military Academy for some ten or twelve years. An appraisal of his book by a mathematician is, "His works are collections of rules rather than expositions of principles, and are wanting in analysis. Gregory is at his best when he descends to the minutiae of practice" (8). While there is an element of truth in this contention it should be remembered that it is the opinion of a mathematician rather than of an engineer.

Following or along with Gregory is another English text, "A Treatise on Mechanics," by Rev. B. Bridge. His work is somewhat the same as Gregory's though much shorter. He starts out with "composition and resolution of motion," from which he infers that the same relation holds for forces as for motion, an inference which Gregory specifically rejects. Bridge employs the method of proportions though in some cases he sets up the equations of equilibrium but without using that notation. He introduces fluxions in a number of places but does not utilize the method of work and energy. He discusses constant and variable forces, the motion of various bodies, especially of projectiles and "collision of bodies," the motion of bodies on inclined planes, rectilinear and curvilinear motion, levers, screws, pulleys, tension in cords and stresses in beams. Many special cases are worked out.

Bridge's book is unusual and is a pioneer in one important respect, viz., many numerical problems are set up and solved in order to illustrate the general principles discussed. He also includes some numerical problems, "Questions for Practice," for the student to solve, though the answers are usually given. One of these problems is the familiar one of the time required for a body to fall to the bottom of a well. Another is typical, "A weight of 2 lb. (W) descending upon a plane whose elevation is 45°, draws another weight (W') of *one lb.* up a plane whose elevation is 30°; what proportion does the force *which accelerates W* bear to the force of *gravity?* Ans. $2\sqrt{2}-1:6$."

Another book, somewhat similar to that of Bridge, is Whewell's "An Elementary Treatise on Mechanics." Whewell gives no problems, and, like Gregory, maintains that there is "an estrangement between the theoretical and practical cultivators of Mechanics which is prejudicial to both." Also like Gregory and unlike Bridge, he maintains that the parallelogram law does not of necessity hold for forces because it has been shown to be true for motion. Apparently neither of these people had grasped the notion of a directed quantity, a vector, as we now know it and they felt that each proposition must be shown to be true separately. Newton and Varignon with their enunciation of the parallelogram law and Euler with his resolution of forces into rectanglar components must have recognized the significance of directed quantities, vectors, but some of their followers did not understand this idea.

Though not in chronological order, one cannot pass over in silence at this time that extremely important textbook, "A Manual of Applied Mechanics, 1858," by Rankine. This book, together with the other writings of Rankine, exerted a remarkable influence on engineering thought and practice. Yet there seems to be little record of its use in engineering schools

in this country, at least the writer has found only two such records; viz., at the University of Tennessee in 1880–1890 and Virginia Military Institute, 1887–1888.

An Early American Book

At the outset it must be remembered that the early American textbooks on mechanics were written by mathematicians and physicists. These writers did not have the outlook of an engineer and consequently their presentations are highly mathematical, logical and formal rather than engineering in character.

Probably the first American writer who had a large influence on the subject matter of mechanics as taught in colleges, and therefore indirectly in engineering schools, was Denison Olmsted at Yale University. His book on "Natural Philosophy" was written in 1831, was revised and stereotyed in 1844 and later revised by various authors, the latest revision being in 1891. Though written primarily for the students at Yale, it was used at Dartmouth in 1834 and "came to be almost universally used in our colleges" (9). Olmsted says at the beginning of the mathematical section on mechanics, which comprises 165 pages (the entire section labelled mechanics contains 259 pages), that he is basing his work on Bridge though he refers to a number of other writers.

Olmsted's work contains over a hundred unsolved examples or problems to which the answers are given. He considers this an innovation for he mentions it in the preface where he says, "a great variety of Problems are annexed to each chapter. . . . Problems hold so important a place in the estimation of the writer, that he has introduced them into various parts of the work . . . it is difficult to account for the fact that, treatises on Natural Philosophy have, in general, contained few or no problems." One of his problems is suggestive, "A ship weighing 336,000 lb. is dashed against the rocks in a storm with a velocity of 16 miles per hour; with what momentum did she strike? Ans. 7,884,800 lbs." (Note the unit in the answer.)

An American Translation

In view of the strong influence of the French school in the United States Military Academy it is not surprising that Gregory did not entirely satisfy those who taught mechanics from it. As previously indicated Boucharlat's work was introduced in the French edition in 1831 and was used for two years, after which it was translated into English and used until about 1850. This translation was apparently the first textbook of mechanics specifically prepared in America for what might be termed technical or engineering students. Since it was used for a long time some details seem desirable and they follow. The book was called *

An Elementary Treatise on Mechanics

Translated from the French of
M. Boucharlat

With Additions and Emendations Designed to Adopt it to the use of the Students of the U. S. Military Academy

by Edward H. Courtenay
Professor of Natural and Experimental Philosophy at the Academy

1833

The translator says in the preface that he has added and omitted some

* The copy examined was borrowed by the Library of the University of Illinois from the John Crerar Library, Chicago.

topics or the treatment of certain topics and, "in supplying the deficiencies of the original, reference has been had frequently to the works of Poisson, Francoeur, Navier, Persy, Genieys, and Gregory." He also states in the preface that "The works of Boucharlat have long enjoyed an unusual share of public favor."

There are no diagrams in the body of the text but there are nine folded plates in the back containing a total of 254 figures. The contents are as follows:

Part First—Statics (which includes Strength of Materials), pp. 1–185.
Part Second—Dynamics, pp. 187–347.
Part Third—Hydrostatics, pp. 349–406.
Part Fourth—Hydrodynamics, pp. 407–432.

He discussed the customary topics of force systems, center of gravity, lever, wheel, inclined plane, motion, simple pendulum (7 pages), compound pendulum (6 pages), projectiles in a vacuum and in a resisting medium, impact of elastic bodies, principle of D'Alembert, moment of inertia. He discusses plane motion and the principle of the motion of the mass center, though these terms do not appear. The topic of work is handled in two pages. Of course there is nothing in the nature of the analysis of a truss or frame. The calculus is used freely and the method of proportions rather than the development of equations is employed in statics. Many of the analyses and discussions are quite academic, as for instance the six and one-half pages devoted to the catenary without a hint of any use which may be made of the analysis. There are 5 or 6 numerical problems worked out but no problems for the student to solve.

Boucharlat recognized that there was more material than could be covered by all groups and he indicated some articles which might be omitted if the time were limited; one of these topics was entitled, "On the System of the World," 19 pages, and another was, "Of the Conditions of Equilibrium of a Point acted upon by several Forces, and subjected to the condition of remaining constantly on two curved Surfaces, or on a Curve of double Curvature," 3 pages.

A Strictly American Textbook

The next American textbook on the subject was "Synthetical Mechanics" by W. H. C. Bartlett. He was a graduate of the United States Military Academy, Class of 1826, and taught there as Professor of Natural and Experimental Philosophy from 1834 to 1871. "Synthetical Mechanics" was based on or was a translation of a work by J. V. Poncelot. It was based on geometrical considerations rather than upon the calculus. It is strange that Bartlett should have used the geometrical method in writing a textbook for he was said to "despise geometry" (10). There was strong protest from some of the teachers at West Point when it was proposed to use it there and after three years it was superseded by another book by Bartlett called "Elements of Analytical Mechanics," which might well be called the first American textbook on mechanics.

Of his "Elements of Analytical Mechanics" Bartlett says in the preface, "The following pages were mainly prepared several years ago for the use of the author's classes in the United States Military Academy. Their publication has been unavoidably postponed to the present time. . . ." Of the book and its method of approach one critical mathematician called it

"The first American work of its kind which starts out with, and evolves everything from, that precious intellectual acquisition of the nineteenth century—the law of the indestructibility of matter and energy" (11). The work is exceedingly abstract, uses the calculus constantly, discusses many special cases, solves a few examples, mostly in terms of symbols, but gives no problems for the student to solve.

Concerning the philosophy of the presentation, he says in the preface, "In accordance with the suggestions of much experience in the business of teaching, all unnecessary divisions and sub-divisions have been avoided. They too often divert the mind from what is essential to that which is merely accidental. . . . All physical phenomena are but the necessary results of a perpetual conflict of equal and opposing forces, and the mathematical formula expressive of the laws of this conflict must involve the whole doctrine of Mechanics. The study of Mechanics should, therefore, be made to consist simply in the discussion of this formula. . . ." He does not state explicitly the formula to which he refers but it is the principle of virtual velocities or the conservation of energy which he develops elaborately.

$$\Sigma P \cdot \delta p - \Sigma m \cdot \frac{d^2 s}{dt^2} \cdot \delta s = 0$$

He sets up equations of work and energy, impulse and momentum, force, mass and acceleration though he does but little with acceleration and does not define the term. Equilibrium is discussed by saying "that *whenever several forces are in equilibrio, the algebraic sum of their virtual moments is equal to zero;* and in this consists what is called the principal of virtual velocities" (12). In demonstrating mathematically the truth of the above statement Bartlett used a device called a *muffle,* consisting of a number of pulleys and cords, to maintain equilibrium and if necessary to give an infinitely small motion to the body in equilibrium.

After he has set up general principles he proceeds to deal with various topics in statics; center of gravity, projectiles, orbits, impact. For the center of gravity of a circular arc he first develops the equation for the center of gravity of a plane curve and substitutes in it the equation for the arc of a circle. An example of the forms of expression used is *"the center of gravity of a circular arc is on a line drawn through the centre of curvature and its middle point, and at a distance from the centre equal to a fourth proportional to the arc, radius and chord"* (13). Rather strangely he does not derive directly the value for the center of gravity of the area of a circular sector but instead uses the method of dividing the area into small triangles and applying the equation for the center of gravity of a circular arc. He does not mention trusses or the determination of the stresses in trusses.

New Writers Appear

The fact that it was nearly twenty-five years after Bartlett's "Analytical Mechanics" was published before a comparable text appeared suggests that mechanics and engineering were both in a rather static state. The next writer was DeVolson Wood, a graduate of Rensselaer Polytechnic Institute, who came to the University of Michigan to teach civil engineering in 1857. He remained until 1872 when he went to Stevens Institute of Technology to become Professor of Mathematics and Mechanics. He was a

strong man, wrote strong books, and left his impression permanently on engineering teaching. In 1876 he published "The Elements of Analytical Mechanics." The edition examined in connection with this paper was the fourth, written in 1884. The preface says, "The plan of this edition is the same as the former one." It is highly mathematical, with many academic discussions. He uses force-mass-acceleration, work-energy and impulse-momentum methods but does not emphasize virtual velocities which he covers in six pages. The book contains a goodly number of problems, some distinctly engineering in flavor, but many are astronomical in character. There are only a limited number of problems on trusses and frames.

The next book to be mentioned is the "Elementary Treatise on Mechanics" of Professor W. G. Peck which was published in 1870. Professor Peck, who taught at the University of Michigan between 1855 and 1857, was a son-in-law of Professor Charles Davies, who wrote a most important series of mathematical textbooks ranging from arithmetic to calculus, and who was for a long time a teacher at West Point. Peck states in the preface that he desired "to produce a book which should form a suitable connection link, between purely popular works, on the one hand, and those of the highest grade on the other." It was intended for study in colleges, did not use the calculus, and was an excellent little book in many ways. The equations were in the form in which they are now used but the units were confused; distance, velocity, and acceleration all had the same unit, feet. In 1887 Peck produced another book entitled "Elementary Treatise on Analytical Mechanics." This was slightly more advanced than the earlier one and used the calculus freely. However, it contained the same confusion of units which appeared in the 1870 publication. The 1887 book contained 95 problems, in statics and kinetics, with answers given. It emphasized force, mass and acceleration, and included a fair amount of work and energy.

Expansion of Engineering Education

The Morrill Land Grant Act of 1862 and the general industrial development following the close of the Civil War caused the establishment of many schools of engineering. The magnitude of this expansion is shown by the fact that in 1866 only "six engineering colleges of established reputation" existed and that only 300 men had been graduated in the preceding thirty-one years while by 1870 there were twenty-one colleges and 866 graduates (14).

Partly as a result of the increased demand for various types of mechanics textbooks, of the advances being made in practical engineering and of the progressive viewpoint of a number of strong teachers, there were a number of textbooks of mechanics written between 1880 and 1890, including Bowser, Lanza, Church and Michie. The one by Bowser, "An Elementary Treatise on Analytical Mechanics," is so remarkable in one respect that it demands special mention.

The book was copyrighted in 1884, the sixth edition is dated 1892 and another edition is dated 1923. The total issue was 17,000 but the remarkable fact is that it started out with 511 pages and ended with 511 pages. The term "edition" as used in this book must mean printing but still it is remarkable that, with such a large sale, the number of pages did not change in 39 years. The book is highly mathe-

matical and theoretical with 615 unsolved problems which lean toward astronomy and contain very few examples of modern engineering. There are no trusses or framed structures and free-body diagrams are neither used nor mentioned. While most of the work is analytical some of it is geometrical. He used both force-mass acceleration and work-energy methods.

Michie's book, "Elements of Analytical Mechanics," was published in 1887, and was highly theoretical. He did not deign to discuss the analysis of a truss but gave graphical analyses of a number of trusses, these examples being taken from Levy's "La Statique Graphique," 1874. Michie says, "While the computation of these stresses can be made by the usual analytical methods, the processes of graphical statics are so simple and accurate as to make them of frequent application" (15). He then goes on to say regarding trusses that "the further development more properly belongs to applied mechanics in Civil Engineering." Yet he gives elaborate analyses of such machines as the screw, inclined plane, pulley, wheel and axle, wedge, and lever. He does not discuss equilibrium by setting the sum of the forces and moments equal to zero but states that "When a body is in a state of equilibrium . . . the acceleration factors in the general equation of energy become separately equal to zero, and there can then be no change of potential into kinetic energy, or the reverse" (16). He followed Bartlett in giving strong emphasis to the method of virtual velocities or what might be called the kinetic rather than the static method of approach. Michie may be said to have perpetuated Bartlett's philosophy of mechanics.

This strong emphasis on the theoretical, the scientific, was probably a result of the highly theoretical approach by the French school of thought. Its influence on engineering was well stated by Merriman nearly fifty years ago when he says, "Engineering courses of study a quarter of a century ago were scientific rather than technical . . . engineering practice was rarely discussed . . . , yet the scientific spirit that prevailed was mostly praiseworthy. . . . Gradually . . . the scientific school developed into the engineering college" (17).

Lanza's "Applied Mechanics," published in 1885, is much less theoretical than the books previously mentioned. It includes trusses and employs the method of sections as well as graphical methods. He does not use the term "free-body diagram" though the idea is involved in the analysis of the stresses in trusses by sections. He derives work-energy, force-mass-acceleration and impulse-momentum relations but does not use virtual velocities. He does not solve many problems and does not give many for the student to solve.

An Engineering Textbook

In 1887 I. P. Church brought out "Mechanics of Engineering," the first really engineering textbook on mechanics published in America. He uses free-body diagrams and so far as the writer has been able to discover is the first writer to use that term. He refers to "two-force pieces" where the forces are collinear with the axis of the piece. He devotes only a short chapter to virtual velocities and sets up and uses force-mass-acceleration and work-energy relations but seems to make little or no use of impulse-momentum relations. A considerable number of engineering problems are

worked out with numerical values and others are given for the student to solve. On the whole the treatment of statics and kinetics is short, only 194 pages, but it has a distinctly engineering flavor not found in any earlier American textbook on mechanics. The warmth of its reception is indicated by the issue of 24,000 copies.

Another book which reached a measure of popularity was T. W. Wright's "Elements of Mechanics." It was published in 1896 and went through a number of editions, the latest in 1909. Some of the problems, of which there are many, are academic rather than engineering. One interesting feature is the large number of short historical items which it contains, telling who originated certain terms and principles.

A Changed Viewpoint

In spite of all the excellent changes which had been made in textbooks something was still lacking and that something was well stated by Professor Mansfield Merriman. In his S.P.E.E. presidential address in 1896 he referred to the great thoroughness with which mathematics was taught, and declared, "The most fundamental . . . change . . . must be . . . a partial abolition of the formal logic of the textbooks and an introduction of historical and utilitarian ideas. Next to mathematics comes mechanics. . . . In most institutions the rational is separated from the applied mechanics and often taught by the mathematical department. Probably less improvement has resulted in the teaching of rational mechanics during the past quarter of a century than in any other subject" (18).

In 1903 E. R. Maurer brought out his book "Technical Mechanics" and with this we have a completely modern textbook of mechanics. Force-mass-acceleration, work-energy, and impulse-momentum relationships are all used; trusses are analyzed by the use of the free-body diagram, though the term is not used, and the problems are engineering rather than academic. The treatment is expanded (Lanza has 229 pages, Church, 194 pages, and Maurer, 381 pages in 4th edition). A large number of problems involving machinery and structures are given and there is a complete abandonment of the highly theoretical, astronomical type of problem. A measure of approval of Maurer by teachers is the 17,000 copies which were printed in the first fourteen years of its existence.

Many other textbooks on mechanics have been written since 1900–1915, but they are essentially the same as Maurer in that they are distinctly engineering in character. The great transition which began to appear in Wood's book in 1876 was continued by Bowser, Lanza and Church to be finally climaxed by Maurer.

What then in brief are the changes in mechanics textbooks? In *content*, much highly theoretical and mathematical material has been eliminated, and in its place the free-body diagram is employed as a tool, frames and trusses are analyzed, and many problems for student solution are added. In *method*, the changes include a shift from stating relationships in terms of proportions to a statement as an algebraic equation and to a wider use of the three approaches, force-mass-acceleration, work-energy, and impulse-momentum, with less use of the principle of virtual work. In *spirit*, a departure from the academic, abstract, formal logic with few applications, to that of an engineering logic with applications to structures and machines. Putting these

changes together they represent a shift from a theoretical, scientific discipline to a serviceable engineering instrument.

Resistance of Materials

Early Textbooks

Unlike mechanics, the principles and laws of the resistance of materials have not been known for a long time. Our knowledge of materials must rest upon experiment rather than upon purely mathematical analysis and, since the philosopher who was accustomed to rationalize often did not experiment, the subject did not progress. Besides that, the means of making accurate measurements were not readily available before about the year 1800. The first attempt at mathematical and experimental analysis of beam action of which we have record is that published by Galileo in 1638. He assumed that the entire cross-section of the beam was under a uniform tensile stress and that the axis for the resisting moment was at the outside of the beam. Many other investigators, mostly mathematicians, showed that this was wrong, though others thought that Galileo was correct. Some of these investigators were Bernoulli, Parent, Mariotte, Coulomb, and, though he did not study beams, Hooke (19).

Therefore, up to about 1820–1830, the theory of beams was not settled and, furthermore, the principal material of which beams were made was wood, mostly in a rectangular shape, for which the theory of Galileo served reasonably well. In France, Girard had published in 1798 the first systematic treatise entitled, "Traité Analytique de la Résistance des Solides et des Solides D'Egale Résistance" and in England Barlow and Tredgold, both practicing engineers, had each published books which, while not entirely correct, were on the right track. Nevertheless there was still much confusion. Stresses in beams were usually considered as belonging to civil engineering rather than to mechanics though some authors included them in textbooks on mechanics.

Gregory's "Treatise on Mechanics," used at the United States Military Academy, 1818–1828 (?), contained a chapter on beams and so we may consider that this was the first textbook used in resistance of materials in the United States. Gregory devoted 29 pages to "Mechanics of Materials." He refers to the theories of Mariotte, Leibnitz, Varignon, Buffon, Euler, Lagrange, and Girard. He regards these theories as "ingenious" but "very complex and intricate." He would, therefore, "prefer the comparatively simple theory of Galileo."

The first proposition which Gregory enunciates is, "The strength of a beam or bar to resist a fracture by a force acting laterally, is as the solid, made by a section of the beam at the place where the force is applied, into the distance of its centre of gravity from the point or line where the breach will end" (20). Six corollaries follow this proposition, one of them being, "the lateral strengths of any beams whose sections are similar figures, are as the cubes of corresponding dimensions of the section." He quotes experiments made by various people but especially those of Banks. He refers to the studies of Emerson on wood, one observation being that a piece of timber which has borne a great weight for a small time broke with a far less weight when left upon it for a longer time. Some caustic comments were made upon the work of Gregory, one such comment being, "Nothing shows more clearly

the depth to which English mechanical knowledge had sunk at the commencement of this century" (21).

Boucharlat's "Treatise on Mechanics," which succeeded Gregory at the United States Military Academy, contained 32 pages on resistance of materials but this topic was indicated as being among those which might be omitted if time were short. Boucharlat adopts the analysis of Leibnitz in preference to that of Galileo, and, except for different notation, the equations he gives for rectangular beams, and these were the only ones considered, are similar to those we use today. The equation given for the deflection of a cantilever beam is correct. Many other equations are given which the writer did not unravel for lack of time, but which are probably similar to those used at present. Thus, the basic approach to a study of a beam as presented by Boucharlat is correct.

However, Boucharlat seems to have no understanding of horizontal shear and no knowledge of the distinction between the correctness of the equations before and after the proportional limit had been exceeded. In one paragraph he suggests a method of finding the modulus of elasticity and the tensile strength as follows. "The best method of determining the values of A [the modulus of elasticity] and B [the ultimate tensile strength] consists in supporting a prismatic solid at its two extremities in a horizontal position, loading it with weights at its middle point, and observing the saggittae [deflections at the center] which correspond to different weights; or simply, the weight and saggita at the instant when fracture is about to take place."

While Olmsted's "Natural Philosophy" can hardly be considered an engineering textbook, he devotes 23 pages in the 1844 edition to this topic. He lays down a number of rules, referring mostly to timber beams, among them being:

(1) "The strength of a beam, resting, horizontally, on its two ends, from a weight on its center, is proportional to the area of a cross-section, multiplied by the depth of its center of gravity"; (2) "In beams of different lengths, resting on two supports, the strength will vary as the area of the section into the depth of the center of gravity, divided by the length into the weight"; (3) "The strength of any bar in the direction of its length, is directly proportional to the area of the transverse section" (22). These are all proportions; if you know the load a given beam will carry, the load a similar beam will carry can be found.

In 1823 the United States Military Academy used a textbook by M. I. Sganzin in engineering construction which, in 1826, was translated into English under the title "An Elementary Course in Civil Engineering." It contained a few pages on the strength of materials and a few pages on the strength of beams, but it is almost entirely descriptive. It cannot be called resistance of materials.

The real teaching of engineering at the United States Military Academy began with the coming there as a teacher of D. H. Mahan. A graduate of the Academy in 1824 he spent some years of study in France and returned to West Point in 1830 where he spent the remainder of his life, 41 years, teaching engineering. His influence on engineering can hardly be overestimated, not only because of his insistence on precision of thought, rigidity of analysis and exactness of execution, but also for his textbooks which were used widely throughout the country

at a time when engineering textbooks were few. As a consequence of these various factors, he exerted a profound influence on the technical or professional aspects of civil engineering education. He shows his high regard for exact and rigorous analysis where, in advising on the books which are desirable for the library of an engineer, he says: "Place in his library every work of science to which M. Navier's name is in any way attached" (23). One of his books, "An Elementary Course in Civil Engineering . . . ," 1837, contained a chapter on materials. He gives a number of equations for beams and columns and these equations, though more detailed than necessary, are similar to those which we use today. They are merely formulas, however, and not developed analyses as we study such topics today.

The effect of the excellent works of Rankine and Weisbach should not be overlooked for they were considered as standard and of the highest order. Rankine was used in a few institutions but never seems to have become a popular textbook.

The New Era in Engineering

From what has been said it will be seen that in a broad way the teaching of resistance of materials in America was most elementary and quite a secondary matter until about the time that an impetus was given technical education under the Morrill Land Grant Act. This is not to say that a number of capable teachers did not understand resistance of materials before that time, but that up to about 1870 structures were built mainly of wood which had been proportioned by custom and experience. Now, however, the expansion and extension of the railroads following the close of the Civil War, the westward migration which accompanied the railroads, and the more plentiful supply of Bessemer steel were all factors which increased the need for a greater knowledge of the resistance of materials.

In 1871 DeVolson Wood produced an entire textbook, 245 pages, devoted to resistance of materials. He states in the preface that it contains "the substance of my lectures . . . during the past few years on the *Resistance of Materials*." He presents a composite of a variety of theories and of experiments. Of the theories, he selects those which seem best and develops equations, some of which are like those we now use and some of which are not like them. This may be said to have been the first American textbook on the resistance of materials. The book ran through a number of editions with numerous changes, but it still maintained its characteristic form, that of presenting a number of theories and a number of experiments, an arrangement which did not make for clarity or definiteness of conclusion in some cases.

Wood was followed in about fifteen years by three other writers on materials: W. H. Burr, Gaetano Lanza and I. P. Church. Two of them combined resistance of materials and applied mechanics. Burr, while a teacher at the Rensselaer Polytechnic Institute, produced a volume of 753 pages in 1883 on "The Elasticity and Resistance of the Materials of Engineering." The book consists of two parts, "Rational," 207 pages, in which the theory of the resistance of materials is developed, and "Technical," 546 pages, where experimental data from many sources are tabulated and analyzed. It includes much material on topics which are now considered as pertaining to

the manufacture of materials. He gives no problems of any kind. In beams he uses a curve in a few cases to show the distribution of bending moment along a beam, but he does not use moment diagrams in the present sense of the term.

Next came G. Lanza, in 1885, at Massachusetts Institute of Technology, with his "Applied Mechanics," which includes both mechanics and resistance of materials. Lanza gives a connected, systematic development of the theories of direct stress, torsion, flexure and columns. Though his book is characterized by himself as "primarily a textbook," it, like Burr's, is actually pretty much of a reference book as many who have used the book in recent times can testify. A small number of problems for solution by the student are given. He shows a number of moment diagrams, but no shear diagrams. In order to find the maximum bending moment he uses the standard method of putting the first differential of the bending moment equal to zero. It is a substantial book.

Then in 1887 came "Mechanics of Engineering" by I. P. Church at Cornell University. This is a book which is built on an excellent teaching plan. It is explanatory in character, conversational in style, with clearly worked out numerical examples, as well as a number of problems for student solution, though the number of the latter is not large. Church, as well as Lanza, and to some extent Burr, includes many cases of advanced topics such as hooks, thick cylinders, flat plates and similar cases. The advent of these three books placed the teaching of resistance of materials on a definitely advanced plane and completely and permanently removed it from the previously brief and exceedingly elementary treatment which it had been accorded.

The new books just mentioned, while more informing, are in the main highly mathematical in expression, and involved in content. They lack a clear-cut, concise simplicity which makes for a popular and easily understood textbook. When one has mastered any of them he is well prepared, but they are difficult to master. They are, with Church possibly excepted, agents in the process of presenting a science which has not yet been fully established. The theories, data and the results of tests are still in the process of being digested and crystallized into a concise, usable form.

At this time came that book which probably more American students of the resistance of materials have studied than any other single book, "Mechanics of Materials," by Mansfield Merriman at Lehigh University. This book was published in 1885 and contained only 151 pages. He states that he is attempting "to logically set forth the principles and theory of the subject." To that end he has not quoted the results of many tests nor has he included much on the more advanced topics, though these advanced topics are considered in later editions. The material is arranged in a series of short articles each dealing with a definite topic or phase of a topic.

There are only a few numerical solutions of problems but nearly all articles include one or two problems for student solution. He shows shear diagrams, the first ones which the writer has observed, as well as moment diagrams. However, the shear and moment diagrams are not combined in the same figure as is customary today. There is no indication that the shear diagram may be used to find the posi-

tion of the maximum bending moment for he gives the mathematical conditions for finding the distance to the section where the shear is zero with distributed loads and then says, "For concentrated loads it will generally be necessary to find by trial the point where the shear becomes zero" (24). In later editions an article is introduced to show the relation between the shear and moment diagrams.

Merriman's book passed through many editions and had a total issue of at least 54,000 copies as compared with 24,000 by his nearest rival, Church. It might be said to be the standard textbook on resistance of materials between 1885 and 1912–1915. Merriman begin to be superseded when J. E. Boyd of Ohio State University brought out in 1911 his "Strength of Materials," which reverted somewhat to the pattern set by Church.

Conclusion

What are the salient points in a century of evolution of resistance of materials textbooks in America? First, a few pages dealing with the theory of Galileo in treatises on mechanics with few if any problems for student solution. Then a voluminous presentation of experimental data and sound, but sometimes rather too elaborate, theory. Finally, a clear exposition of theory supported by basic experimental data and a very large number of excellent practical problems for student solution. The content, as well as the teaching method, has changed from the somewhat arbitrary use of empirical data and rules to that of the careful application of analytical principles to extensive experimental studies.

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Division of Administrative Officers

To the Members of the Administrative Division:

As World War II draws to a close, the reconstruction of a stable national economy in peacetime places upon the industries of this country the heavy burden of providing jobs for millions of workers. This task will be accomplished in two steps, the first of which is reconversion from manufacture of war materials to the making of goods for civilian use, and the second of which is the development of new methods and articles based upon technical advances made under the pressures of war needs. The forerunner of each of these steps is engineering, planning and design. Probably never before in our history has there been so large an engineering operation as that which must be done during the next few years. The rate at which this necessary planning may be accomplished determines the rate at which jobs may be provided and a stable economy achieved.

The function of the engineering colleges is among other things to provide industry with technically trained men. The expansion of industry together with the steadily increasing technical character of its operations is reflected in the increasing rate of training of engineers. From 1910 to 1926 the annual output of engineers increased more than fourfold. By 1942 the number of graduates had reached twice that of 1926. All indications are that this trend of steady growth will continue for a number of years into the future.

Enrollment in engineering colleges rose sharply in 1940; and in 1941 and 1942 the number of engineering students had increased 50 per cent over the number in training during the late thirties. The policy of Selective Service, first in deferring only a limited number of engineering students and then in cancelling such deferment altogether, reduced civilian enrollment in 1943 and since, to those of pre-induction age and a small number of 4-F's. The establishment during this period of the Navy V-12 program, and the adoption by most schools of the accelerated program, made possible the graduation of a substantial number of engineers through 1943 and 1944. In that year the normal trend would have provided 15,000 graduates, and degrees were granted to about 10,500. In 1945 and 1946, the number of degrees earned is estimated to be about 2,500 each year although in 1946 the normal trend would call for 16,000.

With the fighting over, Selective Service continues the policy of no deferment for engineers. Even if such deferment were immediately instituted, anything like a normal output of graduate engineers cannot be reached before 1949, by which time the deficiency below normal trend, accumulated during the years 1943 to 1949 inclusive, will reach an estimated total of 55,000. This is equivalent to saying that industry must get along without hiring engineering graduates for four years, at pre-war levels. In the face of the enormous engineering task in this

country, and in the occupied and other foreign countries, this shortage is in terms of national economic need very serious. If deferment is not immediately instituted, and if conscription continues, the shortage will be correspondingly increased.

In the event that a normal flow of civilian students to the engineering colleges is permitted henceforth, total enrollment by 1947 may, with the return of veterans, reach 120,000 and by 1948 and 1949, 140,000, or an enrollment double that of the middle Thirties. After 1949 it would appear that enrollment may be expected to remain at or above 1941-2 levels.

It should be noted that, although enrollment will climb rapidly and would likely maintain a level equal to any previously experienced, the output of graduates will not provide replacement against the accumulated shortage before 1952, and even then the replacement will probably not exceed 3,000 a year.

Each year that Selective Service is continued without deferment of engineers will increase the shortage by 10,000.

Your committee is keeping in close touch with developments and the writer has spent much time on efforts to obtain recognition of engineering and scientific students in the Selective Service system. Further reports will be made as new developments arise.

S. C. HOLLISTER,
Chairman

Physics Column

With the first issue of the Physics Column—JOURNAL OF ENGINEERING EDUCATION, September 1945, Pg. 82—off press less than three weeks, your chairman has received as yet very little news of the type suggested in this issue. Members of the division are urged not to delay sending in their news to the chairman, J. G. Potter, at A. & M. College of Texas, or to the secretary, C. E. Bennett, at the University of Maine. The chairman has received numerous expressions of opinion that a physics column, such as has been instituted, can be of great service to physics departments in engineering schools. Unfortunately, this can be realized only if members of The Division send in news of the ways in which their departments are improving the programs of physics in engineering colleges.

The chairman also solicits suggestions for the program of the next annual meeting, which will certainly be held at Washington University in St. Louis next June with the joint participation of The American Association of Physics Teachers. Let the chairman know what subjects you would like to see featured in the discussions.

Further expressions of interest are invited, to engage in group or committee studies on various policies in the administering of physics, as outlined in the first issue of the "Physics Column." In the words of one member of The Division who has written the chairman, "The Physics Division of S.P.E.E. is, I am sure, the only means whereby a well planned program for Physics in Engineering can be formulated."

In expressing the opinion that physicists should not leave the direction of physics instruction in engineering colleges to engineers, F. G. Slack, of Vanderbilt University, has written the chairman, "I feel that it is particularly important that physicists themselves consider the problems of physics instruction in engineering schools and formulate plans and programs which will lead to proper fundamental training of our engineering students."

O. C. Lester, of the University of Colorado (retired), has written the chairman with reference to "one problem which will need the attention of the The Division. It concerns the division of time between classical and modern physics for engineering students. . . . Engineering students should know something about the great new developments in the modern field, but outside of electronics, the physics which they need most and will use most is still classical physics. . . . From my point of view we must still teach chiefly classical physics unless more time is given to physics. We are not likely to get much more time except in curricula for physics majors in engineering, such as have been started here and at several other schools."

While engaged in research under the

O.S.R.D. at the time of the last annual meeting, A. C. G. Mitchell sent the chairman the following notes which may contain a valuable suggestion for physics departments: "Our experience in teaching Army students at Indiana University was exceedingly interesting. Our normal peacetime teaching load was about 200 students in undergraduate Physics and at the peak of the Army Program we were teaching 1800 students, plus 200 civilians.

"The results of the Army tests showed that we were very successful in our efforts and I attribute this success in a large extent to our organization of the course. The several points of interest were:

"(1) Enough apparatus was available in the laboratory so that the laboratory work was never more than two weeks removed (in content) from the lecture and recitation work.

"(2) The laboratory was in charge of one man and some assistants so that all material for any laboratory experiment was in place at the beginning of the period.

"(3) Aside from the two hour lecture work, one instructor was in charge of the recitation and laboratory work for any one section of thirty men.

"(4) The recitation work was supervised by one man and weekly conferences were held on the progress of the students.

"(5) Grades and performance graphs by sections were available at the end of weekly or biweekly tests. This had a very good effect on the students and brought forth a spirit of competition."

The University of Southern California has announced the offering of several teaching fellowships carrying stipends of $700 for two semesters. Further information may be obtained from Professor R. E. Vollrath, Department of Physics, The University of Southern California, Los Angeles 7, California.

J. G. POTTER,
Chairman

New Members

ABBOTT, WILLIAM, Ministry of Education, Belgrave Square, London, England. C. H. Colin, H. S. Rogers.

BARBULESCO, C. D., Professor of Engineering, Antioch College, Yellow Springs, Ohio. E. D. Ayres, E. E. Dreese.

BENDER, HARRY A., Associate Professor of Mathematics, Rhode Island State College, Kingston, R. I. T. S. Crawford, E. M. J. Pease.

BENSON, H. K., Professor of Chemical Engineering, University of Washington, Seattle, Wash. R. W. Moulton, E. A. Loew.

BLACKMAN, JAMES S., Instructor in Engineering Mechanics, University of Nebraska, Lincoln, Nebr. E. J. Marmo, T. T. Aakhus.

BROADSTON, JAMES A., Armament Design Engineer, North American Aviation, Inc., 1937 Taft Ave., Hollywood, Calif. F. L. Bishop, Nell McKenry.

BROWN, CARL W., Chief Engineer, Missouri Highway Dept., Jefferson City, Mo. Harry Rubey, H. A. LaRue.

PAUL A. CARTWRIGHT, Instructor in Electrical Engineering, University of Minnesota, Minneapolis, Minn. J. M. Bryant, H. E. Hartig.

CASTONGUAY, THOMAS T., Associate Professor, Acting Head, Dept. Chemical Engineering, University of Kansas, Lawrence, Kansas. J. O. Jones, E. S. Gray.

EDWARDS, FRANKLIN S., Assistant Professor of Aeronautical Engineering, Mississippi State College, State College, Miss. L. L. Patterson, H. C. Simrall, F. S. Edwards.

EMBLER, WELLER B., Professor of English, Head, Dept. Humanities, Cooper Union, New York City. E. S. Burdell, G. F. Bateman.

HARDING, SAMUEL R., Supt. Manufacturing Laboratory, State University of Iowa, Iowa City, Iowa. H. O. Croft, R. M. Barnes.

DRAPER, CHARLES S., Professor of Aeronautical Engineering, Massachusetts Institute of Technology, Cambridge, Mass. R. S. Williams, J. R. Killicawy.

FITZPATRICK, THOS. K., Professor of Architectural Engineering, Iowa State College, Ames, Iowa. O. R. Sweeney, A. H. Kimball.

HUMPHRIES, POWELL H., Instructor in Electrical Engineering, Franklin Technical Institute, Boston, Mass. B. K. Thorogood, W. L. Hughes.

JURAN, JOSEPH M., Professor and Chairman, Dept. Administrative Engineering, New York University, N. Y. C. D. B. Porter, R. C. Price.

KARGER, DELMAR W., Supervisor, Scholarships and Graduate Study, Westinghouse Electric Corp., Pittsburgh, Pa. J. C. McKeon, G. D. Lobinger.

KRAUSS, HERBERT L., Assistant Professor of Electrical Engineering, Yale University, New Haven, Conn. A. G. Conrad, Felix Zweig.

LECAIN, GEORGE H., Assistant Professor of Mechanical Engineering, University of Maine, Orono, Me. I. H. Prageman, H. D. Watson.

LUSK, JAMES B., Associate Professor of Mechanical Engineering, South Dakota State College, Brookings, S. D. H. M. Crothers, W. H. Gamble.

MILLER, SHELBY A., Chemical Engineer, E. I. duPont de Nemours Co., Wilmington 270, Del. T. H. Chilton, R. C. Ernst.

MILLS, ROBERT W., Instructor in Mechanical Engineering, University of Nebraska, Lincoln, Nebr. N. H. Barnard, W. F. Weiland.

MINGINS, CHARLES R., Associate Professor of Physics, Tufts College, Medford, Mass. H. P. Burden, F. N. Weaver.

MUNGER, HAROLD H., Instructor in Applied Mechanics, Kansas State College, Manhattan, Kansas. L. V. White, C. H. Scholer.

PASEK, J. EDWIN, Manager, Industrial and Technical Dept., Prentice Hall, Inc., New York City. C. Magnuson, W. J. Luzader.

ROLFE, WALTER T., Professor and Chairman, Dept. Architecture, University of Texas, Austin, Texas. P. M. Ferguson, W. R. Woolrich.

SEILER, JOHN N., Assistant Professor of Engineering Extension, Pennsylvania State College, State College, Pa. L. A. Doggett, A. P. Powell.

SINGLETON, JOSEPH L., Manager, Methods and Planning, Allis-Chalmers Mfg. Co., Milwaukee, Wis. T. T. Agthe, W. D. Bliss.

SMITH, REUEL L., Associate Professor of Mechanical Engineering, University of Cincinnati, Cincinnati, O. R. E. Hundley, C. A. Joerger.

WALTON, JESSE S., Professor and Acting Head, Dept. Chemical Engineering, Oregon State College, Corvallis, Ore. A. L. Albert, G. W. Gleeson.

WRIGHT, DANIEL K., Assistant Professor of Mechanical Engineering, Case School of Applied Science, Cleveland, Ohio. G. B. Priester, G. L. Tuve.

89 new members this year.

College Notes

University of Maine.—*New Appointments.* Professor of Civil Engineering—Hamilton Gray, A.B.—Harvard College, 1933; M.S.—Harvard Graduate School of Engineering, 1934; Sc.D.—Harvard Graduate School of Engineering, 1938.

Professor Gray will have charge of the courses in Soil Mechanics, and will also be on a consulting basis for the Maine State Highway Commission.

Instructor in Electrical Engineering—Kenneth L. Parsons, B.S.—University of Maine, 1934.

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200 A.S.T.P. students are in attendance in Advanced Engineering in the Departments of Civil, Electrical, and Mechanical Engineering.

Sections & Divisions

Dear Dr. Bishop:

At a special meeting of the Pennsylvania State College Branch, S.P.E.E., at the end of the Faculty meeting of the School of Engineering on Monday, July 9th, the following were elected to office for the year 1945–46:

Chairman: E. B. Stavely.
Vice-Chairman: J. S. Doolittle.
Secretary: J. W. Breneman.

ALBERT P. POWELL, *Secretary.*

Graduate Studies

The officers for the new division of Graduate Studies of the S.P.E.E. are:

Chairman: L. E. Grinter, Vice President, Illinois Institute of Technology.
Vice Chairman: S. C. Lind, Dean, University of Minnesota.
Secretary: F. T. Mavis, Head Dept. Civil Engineering, Carnegie Institute of Technology.